PERFORMANCE MODELLING AND ANALYSIS OF A NEW COMP-BASED HANDOVER SCHEME FOR NEXT GENERATION WIRELESS NETWORKS

RR AHMED

Ph.D

UNIVERSITY OF BRADFORD

2017

Performance Modelling and Analysis of a New CoMP-based Handover Scheme for Next Generation Wireless Networks

Performance Modelling and Analysis for the
Design and Development of a New Handover Scheme for Cell Edge Users in
Next Generation Wireless Networks (NGWNs) Based
On The Coordinated Multi-Point (CoMP) Joint Transmission (JT) Technique

Rana Rashid AHMED

Submitted for the Degree of

Doctor of Philosophy

Faculty of Engineering and Informatics

School of Electrical Engineering and Computer Science

University of Bradford

2017

Abstract

Rana Rashid Ahmed

Performance Modelling and Analysis of a New CoMP-based Handover Scheme for Next Generation Wireless Networks

Performance Modelling and Analysis for the Design and Development of a New Handover Scheme for Cell Edge Users in Next Generation Wireless Networks (NGWNs) Based on Coordinated Multi-Point (CoMP) Joint Transmission (JT) Technique

Keywords: *Coordinated Multi-Point (CoMP), Inter-Cell Interference, Unnecessary Handover, Reference Signal Received Power (RSRP), Received Signal Received Quality (RSRQ), cell edge*

Inter-Cell Interference (ICI) will be one of main problems for degrading the performance of future wireless networks at cell edge. This adverse situation will become worst in the presence of dense deployment of micro and macro cells. In this context, the Coordinated Multi-Point (CoMP) technique was introduced to mitigate ICI in Next Generation Wireless Networks (NGWN) and increase their network performance at cell edge. Even though the CoMP technique provides satisfactory solutions of various problems at cell edge, nevertheless existing CoMP handover schemes do not prevent unnecessary handover initialisation decisions and never **discuss** the drawbacks of CoMP handover technique such as excessive feedback and resource sharing among UEs. In this research, new CoMP-based handover schemes are proposed in order to minimise unnecessary handover decisions at cell edge and determine solution of drawbacks of CoMP technique in conjunction with signal

measurements such as Reference Signal Received Power (RSRP) and Received Signal Received Quality (RSRQ). A combination of calculations of RSRP and RSRQ facilitate a credible decision making process of CoMP mode and handover mode at cell edge. Typical numerical experiments indicate that by triggering the CoMP mode along with solutions of drawbacks, the overall network performance is constantly increase as the number of unnecessary handovers is progressively reduced.

Declaration

I hereby declare that this thesis has been genuinely carried out by myself and has not been used in any previous application for a degree. The invaluable participation of others in this thesis has been acknowledged where appropriate.

Rana Rashid Ahmed

Dedications

This thesis is dedicated to my beloved parents, beloved wife and

my beloved sons (Mashhood and Shehroz) and my beloved sisters and brothers.

Acknowledgement

First and foremost I would like to express my sincere gratitude to my principle supervisor *Professor Demetres Kouvatsos* for the continuous support of my research study, for his patience, motivation, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my research study.

I thank my fellow researcher especially *Mukhtar Bello* and *Ashraf* for the stimulating discussions, for the sleepless nights we were working together before deadlines, and for all the fun we have had in the last few years.

Last but not the least, I would like to thank my family for their love and encouragement. For my parents who always motivated me to achieve high ranks in education. For my wife *Mehreen Rashid who* always helped me a lot to get the success, waiting me long time at home with my kids. For my Son *Mashhood Ahmed*, who always give me reminder "please Baba do your PhD quickly and then we will got to Disney Land". For my new born son *Shehroz Ahmed*, I missed him a lot during time I spent in the labs at end of my thesis writing and for my brothers and sister for supporting me spiritually throughout writing this thesis and my life in general.

Publications/Presentations

Workshops

RR Ahmed, and D. D. Kouvatsos, "*Analytical Modelling of Coordinated Multi-Point (CoMP) based handover for Next Generation Wireless Networks (NGWN)*" Research Workshop NetPSEn 2015 on 'Networks and Performance-Security Engineering', Monday 21st Dec. 15.

RR Ahmed, and D. D. Kouvatsos, " *An Efficient CoMP-based Handover Scheme for Next Generation Wireless Networks*" 33rd UK Annual Performance Engineering Workshop (UKPEW) 2017, Monday 11th Dec. 17.

Seminars

RR Ahmed and D. D. Kouvatsos, "*Performance Analysis and Modelling a New Handover Scheme for Cell Edge Users in Next Generation Wireless Networks (NGWNs)"* University of Bradford ACM 'Association for Computing Machinery' Seminar, Bradford, Thursday 20th August,

2015.

Journals

RR Ahmed and D. D. Kouvatsos, "*An Efficient CoMP-based Handover Scheme for Next Generation Wireless Networks to Reduce Unnecessary Number of Handovers at the Cell Edge*" to Submit Soon to Electronic Notes in Theoretical Computer Science, https://www.journals.elsevier.com/electronic-notes-in-theoretical-computer-science/.

RR Ahmed and D. D. Kouvatsos, "*Optimised Feedback and Resource Sharing Process During CoMP-JT Based Handover in LTE-A Systems for Cell Edge User*" is preparing to submit Soon to Electronic Notes in Theoretical Computer Science, https://www.journals.elsevier.com/electronic-notes-in-theoretical-computer-science/

.

Acronyms

1G	First Generation
2G	Second Generation
3G	Third Generation
4G	Fourth Generation
5G	Fifth Generation
3GPP	Third Generation Partnership Project
ABS	Almost Blank Subframe
AHM	Adaptive Hysteresis Margin
AMPS	Advanced Mobile Phone System
CDMA	Code Division Multiple Access
CCS	Coordinated Multipoint Cooperative Set
CTP	Coordinated Multipoint transmission Set
CoMP	Coordinated Multi-Point
CS/CB	Coordinated scheduling and Coordinated beamforming
CSI	Channel State Information
CQI	Channel Quality Indicator
dB	decibel
DwPTS	Downlink Pilot Time Slot
EDGE	Enhanced Data GSM Evolution
eICIC	Enhanced Inter Cell Interference Coordination
eNB/eNodeB	Enhanced Node B (evolved Node B)
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
ETSI	European Telecommunication Standard Institute
FDD	Frequency Division Duplex
GP	Guard Period
GPRS	General Packet Radio Service

GSM	Global System Mobile
GSPN	Generalised Stochastic Petri Nets
HOM	Handover Margin
HM	Hysteresis Margin
HSDPA	High Speed Downlink Packet Access
ICIC	Inter-cell Interference Coordination.
IMT-A	International Mobile Telecommunication Advanced
ITU	International Telecommunication Union
JP	Joint Processing
JT	Joint Transmission
JATCS	Japanese Total Access Communication System
LTE	Long Term Evolution
LTE-A	Long Term Evolution- Advanced
MME	Mobile Management Entity
MCS	Modulation and Coding Scheme
MU-MIMO	Multi User- Multiple Input Multiple Output
NTT	Nippon Telephone and Telegraph
NMT	Nordic Mobile Telephone
NGWNs	Next Generation
OFDMA	Orthogonal Frequency Division Multiple Access
OFDM	Orthogonal Frequency Division Multiplexing
PDSCH	Physical Downlink Share Channel
PDC	Pacific Digital Cellular
PN	Petri Nets
RB	Resource Block
RSRP	Received Signal Received Power
RSRQ	Reference Signal Received Quality
RSSI	Received Signal Strength Indicators

RRH	Remote Radio Heads
SGW/PDNGW	Serving Gateway/Packet Data Network Gateway
SINR	Signal Interference plus Noise Ratio
TDD	Time Division Duplex
TACS	Total Access Communication System
TP	Transmission Points
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
TTT	Time-To-Trigger
TTI	Time Transmission Interval
WCDMA	Wideband Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access
UE	User Equipment
UICC	Universal Integrated Circuit Card
UMTS	Universal Mobile Telephony System
UpPTS	Uplink Pilot Time Slot

List of Figure

List of Tables

Table of Contents

Chapter 1: Introduction

1. Introduction

In Past few years, numerous telecommunication groups are trying to accomplish the milestones of Fourth Generation (4G) and Fifth Generation (5G) mobile networks. Moreover, International telecommunication Union (ITU) defined the standard for 4G, called International Mobile Telecommunication Advanced (IMT-Advanced) [1]. The core milestones of IMT-Advanced are high data rate, enhanced system capacity, seamless mobility and reduce cell edge interference and for IMT-2020, they have plane to launched 100 times faster network as compare with the previous generations such as 2G and 3G [2] [3]. 5G networks are mainly focus on business, they will contact whole world with high speed data rate. Therefore the e-commerce business and social cites become more popular across the globe. The standardization is not finalised for 5G networks, mobile companies are working on it, and they will give their suggestion in 2019 conference that will be organised by ITU-R to finalise the requirements of 5G networks [4] [5].

The Worldwide Interoperability for Microwave Access (WiMAX) and Third Generation Partnership Project (3GPP) are two main participants of 4G and 5G networks, completing the requirements of IMT-Advanced and IMT-2020 standards. Although, WiMAX has completed many requirements of IMT-Advanced, but ITU conferred 3GPP's technology termed 'Long Term Evolution' as 4G network. In addition, the 3GPP group is also very close to accomplish the requirements of 5G network [6] .

To accomplish requirements of IMT-A, 3GPP's introduced many new technologies such as carrier aggregation, Multiple Input Multiple Output (up to eight layers), Coordinated Multi-Point (CoMP) [7]. With help of these techniques, the solution of most challenging issues such as 'cell edge interference' and 'Inter Cell Interference (ICI)' [8] [9] .are possible. In addition, these issues are main cause of unnecessary handovers in Next Generation Wireless Networks[1] (NGWN). Therefore, in this thesis Coordinated Multipoint technique is adopted to find the solutions of unnecessary handovers at cell edge region of NGWN.

1.1. Long Term Evolution Advanced (LTE-A) Standard

[1] In this report Next Generation Wireless networks are considered as LTE-A, 4G and 5G Networks.

In 2004, LTE was introduced by Third Generation Partnership Project (3GPP), 3GPP is globally recognised telecommunication standard authority. Therefore, LTE is also known as 3GPP Long Term Evolution. Moreover, LTE is evolution of UMTS and GSM, because these two standards were also introduced by 3GPP. So in 2004, they had started work on standardization for LTE, and they have completed most of work until 2008 [10]. The main focus was to increase and improve the system capacity, higher transmission data rate, lower operating cost and reduced latency. Most researchers considered that the LTE-A release 11 is close to the 4G network. Moreover, Multiple Input Multiple Output (MIMO) (i.e.,), Coordinated Multipoint (CoMP), Carrier Aggression techniques make possible to achieve the IMT requirements of 4G and 5G networks [11] [1].

1.1.1. Coordinated Multipoint Technique

Coordinated Multipoint (CoMP) is an advanced technology of LTE-A, it comprises many solutions such as the cell edge interference and intra-cell interference. Although In LTE Release 8, they had included most of protocols and performance features but Coordinated Multi-Point (CoMP) techniques were not part of this release, the reason was the lack of research and difficulties in implementation of

CoMP. In Release 9 to Release 14 CoMP is part of LTE-A standard, Although, LTE-A release 11 includes the CoMP but still it is not fully implemented practically anywhere [7]. In September 2011, after completing the feasibility study on CoMP, 3GPP started work on assumed scenarios of coordination transmission and coordination reception. The assumed deployment scenarios include homogeneous configuration where the points are different cells and heterogeneous configurations that include the low power points e.g. remote radio heads or femtocells [12] [13]. The detail of Coordinated Multipoint is included in second chapter.

1.1.2. The Cell Edge Interferance or Inter-Cell Interference

The Cell edge user throughput is one of challenging issue of wireless industry and it has highest priority to achieve milestone of 4G and 5G networks. Likewise, LTE-A gives the highest priority to this issue in his all Releases[13] [14] [15].

Fig. 1 illustrates the cell edge user area is shaded with red colour, in this area User Equipment (UE) always experience low signal measurements such as quality and power. The causes of this signal drops are; UE has long distance from serving cell and has interference of neighbouring cells [2].

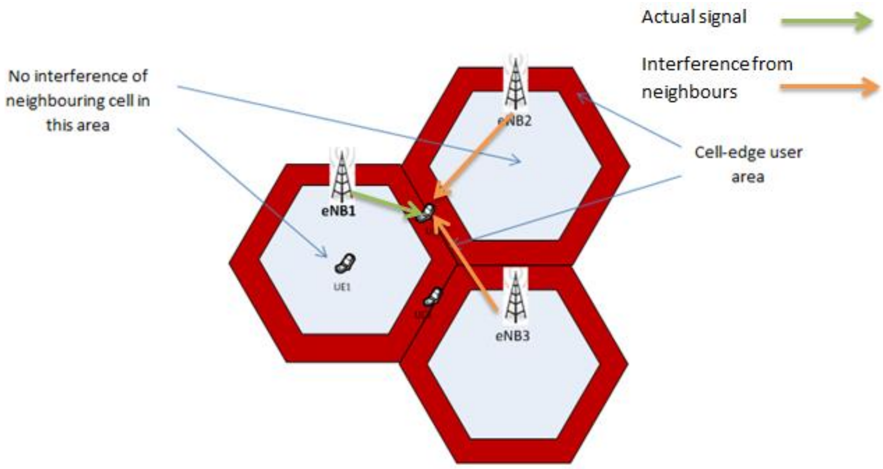

Fig. 1 Overview of The Cell Edge User Interference(c.f., [12])

The white shaded area in Fig. 1 presents high signal measurements for UE. Present research is based on this concept and determine the solutions of users present in the cell edge area.

1.2. Aims and objectives of Thesis

Following are main aims and objective of research.

1.2.1. Aims of Thesis

The aim of research is to find solution of cell edge interference for cell edge users and propose an efficient solution of handover for cell edge users using Coordinated Multipoint-Joint Transmission (CoMP-JT) technique of LTE-A.

1.2.2. Objectives of Thesis

The main objectives of research are;

- Investigate the effectiveness of Coordinated Multipoint (CoMP) technique for Next Generation Wireless Networks
- Compare existing handover techniques used in wireless networks and proposed an effective solution for Next Generation Networks.
- Investigate reliable handover solution based on CoMP JT technique for the cell edge users to reduce to overcome Inter-Cell Interference (ICI) problems.
- To introduce and use COMP JT technique at the cell edge; improve performance, Increase overall throughput and minimise the unnecessary handovers.
- Propose An Efficient CoMP-based Handover Scheme for Next Generation Wireless Networks to reduce unnecessary number of handovers at the cell edge
- Propose optimised solution of radio resources sharing among different users at the cell edge during CoMP-JT based handover in LTE-A systems.

- Propose a reliable solution for CoMP JT technique to overcome the drawbacks such as extra burden and excessive feedback process.

1.3. Research Motivation

According to Cisco's global mobile data traffic report, in 2016, 419 million wireless devices and connections were added in mobile industry. Therefore, globally the number of connections increased from 7.6 billion to 8 billion from 2015 to 2016 and they predicted that by 2021 there will be around 11.6 billion devices connected to mobile network globally[17]. Most of these connections and devices are smart phones that have at least 3G connectivity to use the multimedia application and advance computing applications. Cisco reported that globally 46% connections were smart phones in 2016[17]. Therefore, In Next Generation Wireless Networks, the performance of network is highly depended on the mobility of users because the network site consists on many micro (femtocell) and macrocells (eNB) to accommodate all users. As a result, in such overcrowded situations, the mobility is main concern of networks. The handover decisions are increased and overall system throughput is decreased especially at the cell edge because of high Inter-Cell Interference (ICI). Thus, Third Generation Partnership Project (3GPP) team introduced CoMP JT to overcome these problems of the cell edge interference. Therefore, the main scope of present research is highlight the use of CoMP JT technique for handover in sense to avoid unnecessary handover decisions and increased overall system throughput.

1.4. Simulation Tool

For simulation and results many packages are available such as LTE-Sim [18], Ns3 LTE Simulator [19], Vienna LTE-Advanced Simulator [20] and LTE-A System Level Downlink Simulator [21] [22] . All these simulators are supported to LTE-A systems but CoMP-JT technique is not implemented in these simulators. For implementation of solution of proposed handover algorithms required a LTE-A simulator that support to both handover procedure and CoMP-JT technique. Therefore LTE-A System Level Downlink Simulator [22] [21] is used to simulate and evaluation the proposed handover scenarios.

1.5. Outline of PhD Thesis

The thesis is comprised on following five chapters.

Chapter 1 containing overall introduction of thesis along with Aims and Objectives, Research Motivation and simulation tools.

Chapter 2 presents the brief history of Generation of Networks. Moreover the main emphasis of this chapter is on Handover procedure in LTE-A. This chapter contain main information about the handover decision in LTE-A such as concept of handover, procedure of handover, parameters of handover and technical specification of LTE-A required for handover process.

Chapter 3 contains all relevant information about Coordinated Multipoint including different categories of CoMP, CoMP sets, deployment scenarios, and practical example of CoMP. Moreover scheduling types and algorithms are part of this chapter.

Chapter 4 contains, the information of simulator that is used to simulate the results of proposed algorithms of handover schemes

Chapter 5 is presenting a scheme to reduce unnecessary handover decision at the cell edge region. Therefore, this chapter include the introduction, motivation, related results, proposed algorithm, and simulation environment. In addition, results and discussion of proposed scheme are also part of this chapter.

Chapter 6 presents another handover for the cell edge users. Therefore, this chapter include the introduction, motivation, related results, proposed algorithm, and simulation environment. In addition, results and discussion of proposed scheme are also part of this chapter.

Chapter 7 contains the concluding statement along with recommendations for future research

Summary of Chapter 1

Chapter 1 consists of the introduction of present research area. It contains the useful information of 4G and 5G mobile networks that helps to explain the milestones of future networks. The main focus of chapter is on LTE-A systems with its advanced technique called Coordinated Multipoint (CoMP). Moreover, the interest and selection of topic is discussed in details under motivation and Aims and objectives.

Overall, first chapter has all relevant details about the research topic.

Chapter 2: Evolution of Next Generation Wireless Networks and Handover in LTE-A

2. Introduction

2.1. Next Generation Wireless Networks (NGWNs)

In cellular industry, 4G and 5G networks are considered as Next Generation Wireless Networks. To highlight the features of 4G and 5G networks, there is need of overview of 1G, 2G and 3G networks.

2.1.1. 1st Generation (1G) Cellular Networks

The actual evolution of cellular industry was started in 1867, when Maxwell discovered the Electromagnetic waves, but the analogue system deployed in 1980s was considered 1st generation mobile network. The 1G technologies were only related with the voice that transmit during the mobile calls and referred as analogue technology [23][24]. The first complete cellular communication system was launched by Nippon Telephone and Telegraph (NTT-Japan) in 1979 [25]. Furthermore, in same year, Sweden and Norway launched a commercial analogue mobile communication system called Nordic Mobile Telephone (NMT).

Approximately after four years of first analogue mobile network, in 1983, USA introduced Advanced Mobile Phone System (AMPS) with 900MHz band and that were supported to 666 duplex channels. Moreover, Total Access Communication System (TACS) and Japanese Total Access Communication System (JATCS) were introduced in UK and Japan respectively in 1G of mobile network [25] [26] [27].

In 1G network, from base station to handset only 25MHz bandwidth used for forward and return links. In addition, the bandwidth was divided into different parts called channels that were allocated to each user [25]. Therefore the handover existed in same network with limited roaming. The main problems of 1G networks were the limited bandwidth, security, voice quality was poor, and having big and bulky handsets [13]. The most important issue was the mobile subscriber were increasing with rate of 40% globally [29], and 1G networks did not have enough resources to accommodate all subscribers, they had only limited capacity . That was the main reason of deployment of 2G networks [23].

2.1.2. 2nd Generation Cellular Networks

The era of 2nd Generation Cellular Networks was started in 1990s, when digital technology was introduced. These networks were provide the full roaming service along the world with secure and high quality voice. The capacity of users were also increased, According to the research, at the end of 2002, 10% of world population were used cellular networks, the mobile networks were present in 190 countries with 787 million subscribers [23].

The main features of digital technology were forward error correction, voice coding, and higher order digital modulation techniques. So to accommodate more users Code Division Multiple Access (CDMA) and Time Division Multiple Access (TDMA) were used in 2G cellular networks. Global System Mobile (GSM), Pacific Digital Cellular (PDC), Is-136, IS-95 and IS-95A are example of 2G mobile networks [25] [30].

Global System Mobile is one of successful network of this era. It is developed by European Telecommunication Standard Institute (ETSI) and based on two technologies such as TDMA and FDMA. The latest GSM networks operates in

900MHz and 1.8GHz bands except USA, where they are using 1.9GHz Band [8] [31] [32].

In 2G networks, first time digital modulation and advanced signal processing were used. Moreover, as compare with the 1G networks, in 2G networks most of networks offered three times more bandwidth to fulfil the demand of increasing customers and 9.6kbs data rate were supported to each users. Although, 2G networks were having lot of advancement in technology and high data rate but they are not enough to meet the requirements of fast growing subscribers. Therefore, to overcome the problems of 2G networks, 2.5G networks were introduced [33] [34].

In 2.5G networks many new standards were proposed, the aim of these standard were to provide and support fast and reliable communications and new technologies are compatible with 2G networks. General Packet Radio Service (GPRS) and Enhanced Data GSM Evolution (EDGE) were two most successful networks of 2.5G[34] [35]. The GPRS based networks provide all functionality related with the internet browsing, always on, higher capacity and also they were provided the packed based functionality such as colour browsing, visual communication, multimedia messaging etc. Although 2.5G networks accomplished many demands of users but with passage of time, achievements of 2.5G networks were not sufficient for next generation networks. So for high demands of high speed internet and multimedia application 3G networks are introduced [30].

2.1.3. 3rd Generation Networks

3G networks are more advanced and accomplished many demands of users related with the use of internet. 3G networks introduced high transmission speed, wide bandwidth, vast network capacity and international roaming. Moreover, Voice of IP (VoIP), high speed internet access, multimedia service on demand, and video conferencing are possible to use on a small handset [36].

In end of 1995, International Telecommunication Union (ITU) intended to introduce a common wireless standard for all countries based on 2000MHz frequency band. This standard was known as International mobile Telephony 2000 (IMT-2000). Although they were successful to brining people for discussion and talks but at the end this was failed because the wireless community were divided into two different groups such as 3GPP (3G Partnership Project) and 3GPP2. So, the 3GPP were followed Wideband CDMA as air interference technology and 3GPP2 were followed CDMA2000 as air interference technology[37].

So In 2001, Wideband CDMA was launched in Japan, considered as first 3G network [38]. The main application of WCDMA were video conferencing, location based services and mobile television etc. This standard is also known as Universal Mobile Telephony System (UMTS). This standard was based on CDMA air interference technology and having 5MHz wide bandwidth [37] [38].

CDMA 2000, Time Division Synchronous Code Division Multiple Access (TD-SCDMA), and High Speed Downlink Packet Access (HSDPA) are prominent standard of 3G networks.

2.1.4. 4^{th} Generation Networks

The goals of 4G cellular networks are partially achieved in last few years. The research is carry on to accomplish all milestones of IMT-A standard set by ITU. In 2007, ITU community introduced radio interference technology Orthogonal Frequency Division Multiple Access (OFDMA) for 4G networks [39]. In 2008, ITU published requirement for 4G networks, the main requirements are at least 1Gbps data rate for downlink and 500Mbps data rate for uplink [11]. So 3GPP group introduced Long Term Evolution (LTE) standard for 4G network. The Initial Release of LTE did not accomplish the requirements of IMT-A, so that's why it is considered as 3.9G networks. In 3.9G using 20MHz spectrum, the downlink data rate is 100Mbps and for uplink is 50Mbps [40]. Therefore, in latest versions of LTE known as Long Term Evolution-Advanced (LTE-A) is considered as first 4G network, they have achieve 75Mbs uplink data and with spatial multiplexing they have achieve 300Mbps downlink data rate [41].

Although the LTE-A has accomplished the milestone of IMT-A in his Release 10 to Release 14, but according to Cisco 63% mobile data traffic is increased globally in 2016. Moreover, by end of 2015, the data traffic reached up to 4.4 Exabytes per month, and by end of 2016, it is increased and reached up to 7.2. Exabytes per month (1 Exabyte = 1 Billion Gigabyte). In addition, Cisco also predicted that by 2021, the mobile data traffic will be 49 Exabytes. Following graphs shows growth in data traffic from 2016 to 2021 [17].

Fig. 2 Cisco Forecast mobile data per month (2016 to 2021) (c.f., [17])

2.1.5. 5th Generation Networks

According to Cisco, The mobile data traffic is increasing sharply and also the mobile devices used is increased in business world [17]. Almost in whole world, there are many millions of business and sports applications are running on mobile devices. Therefore, mostly 5G networks will be business oriented and will be focus on to handle dense mobile traffic globally. So for this purpose ITU-R already discussed the possible solution and problems with mobile community and they have already triggered the IMT-2020 standard in 2015 for 5G networks [42]. They will finalise the network design parameter in 2019 conference on 5G networks. The main requirements of 5G networks are based on 3G and 4G networks, that's why 3GPP planned to introduce the latest version of LTE standard with name of LTE-beyond or LTE-A+ (still not decided) [4] following picture explain how 5G networks are in progress .

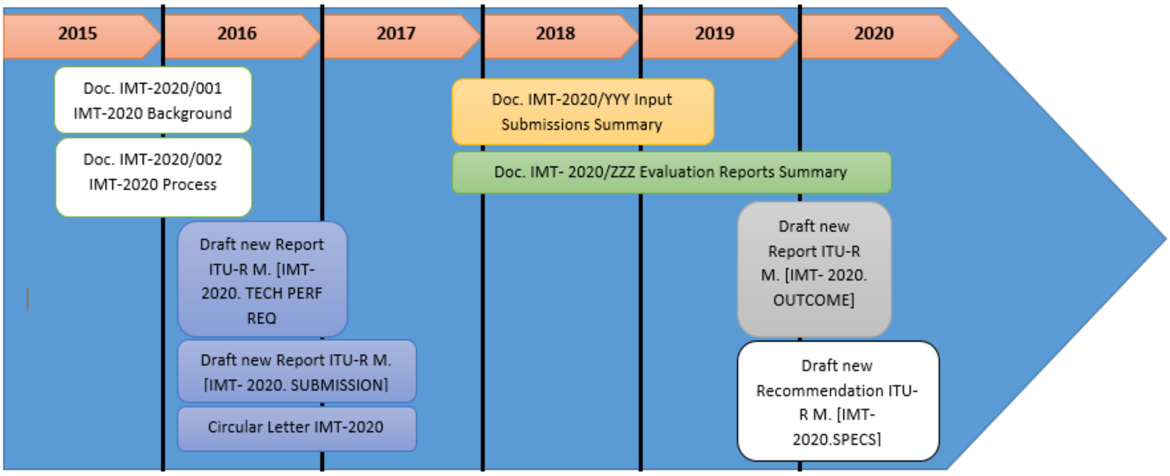

Fig. 3 IMT2020 Milestones (c.f., [4])

2.2. The Concept of Handover

Mobility is playing vital role in cellular technology because the network performance is depending on it e.g. the performance of network is degraded at the time, when users are moving in fast vehicles and handling the mobility of several users during their movements in congested places is challenging task for cellular networks. Cellular technologies introduced term handover or handoff to deal with mobility problems.

Handover is a process in which the control of UE is transferring from one cell to another cell. Many handover protocols involved during the process to ensure the seamless UE movement from one cell to another cell. The main purpose of handover is to minimise the disturbance and provide session continuity to UE [43]. Although, in cellular communication many standards and techniques were proposed for minimising the effects of handovers but LTE has introduced more effective and good techniques as compare with old techniques such as CoMP and Carrier Aggregation. Moreover, LTE provides seamless and fast handover procedure for mobility of various users even they have speed between 350km/h to 500km/h. In such cases the handover occurred very fast and frequently so it is important to provide seamless access and maintain quality of services for end users.

Many handover types are introduced by cellular networks to maintain quality of services of end user. The detail of these handover types are given below.

2.3. Types of Handover

Although in literature, many types of handover are discussed such as Vertical Handover (VHO) (mobile user performs handover between different Radio Access Technology (RAT) e.g. between LTE and WiMax), and Horizontal Handover (HHO) (mobile user performs handover between same Radio Access Technology (RAT) e.g. between LTE and LTE [14] but the main types of handover are categorised as hard handover and soft handovers. The details of these two main categories are given below.

2.3.1. Soft Handover

Soft handover is associated with term 'Make before Break'. That means the user first establish or make connection with the target eNB before cancelling or deactivating the existing connection with the source eNB.

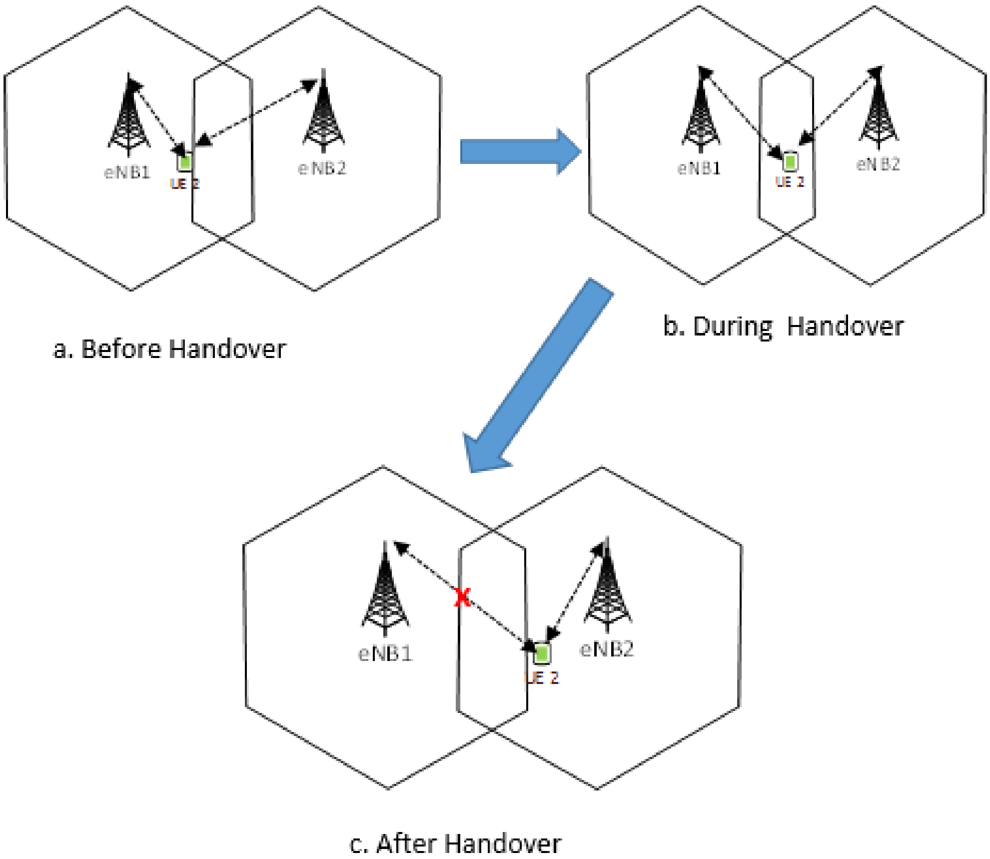

Fig. 4 Example of Soft Handover(c.f., [14])

First time WCDMA introduced soft handover, in which during handover, user maintained at least one connection with existing node before transferring call to target node. It means at a time user is connected with more than one cells. That's why this handover technique is bit difficult or complex as compare with the hard handover. To maintain more than one connections at time is not easy during calls [14] [15].

2.3.2. Hard Handover

Hard handover is associated with term ‘Break before Make’. That means the existing wireless link/connection is broken from source eNB, before establishing or activating the link/connection with target eNB. In hard handover there is only one transmission point for UE [14] [44]. LTE support to only hard handover because the disturbance level is very low at cell edge region during handover procedure. Therefore, in present research the handover schemes are based on CoMP –JT techniques that is useful to reduce the disturbance of neighbouring cells at cell edge region. That’s why for handover procedure they followed the hard handover pattern of transferring control of UE from serving eNB to target eNB. Moreover, the target eNB is always present in the CoMP cooperative set (CCS).

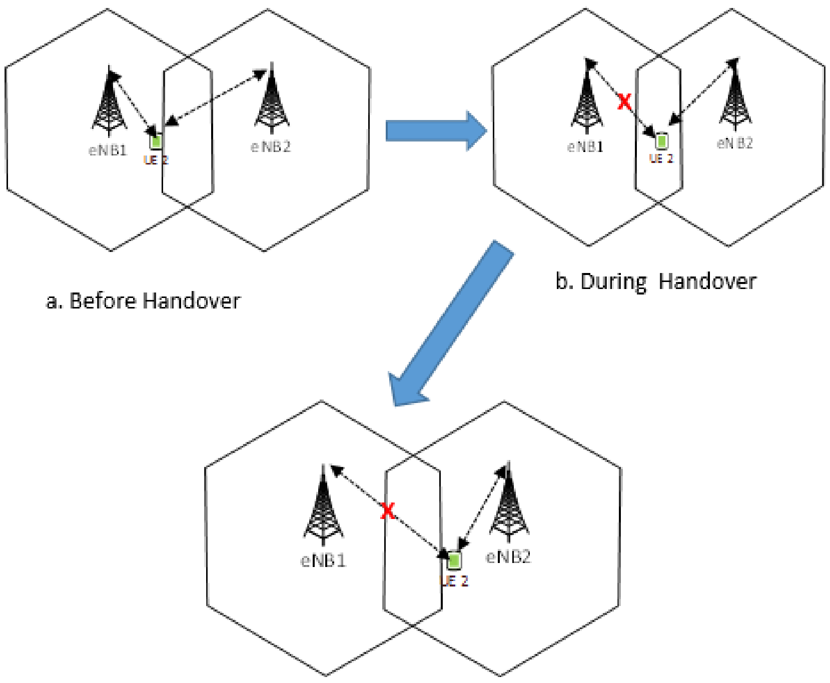

Fig. 5 Example of Hard Handover(c.f., [14])

2.4. Handover Procedure in LTE-A

LTE-A is supported to various user mobility models. Handover procedure in LTE-A is controlled by network and assisted by UE. It means UE sends measurement report to serving eNB, then serving eNB decide the handover procedure.The handover procedure involves three parts in LTE-A [38] [39];

- Handover Preparation
- Handover Execution
- Handover Completion

2.4.1. Handover Preparation

In this part, all nodes such as UE, serving eNB and target eNB are involved in preparation before transferring UE control to new cell. Following are main steps that involved during handover preparation.

- Configure: UE sends the measurement report to serving eNB, when serving eNB configures and triggers the UE measurement procedure [15] [46].
- Decision: On basis of received measurement report from UE, serving eNB takes handover decision.
- Admission control: If the decision is 'Yes' in favour of handover, target eNB consider the QoS information and performs admission control and also target eNB prepares handover.
- Execution: At the end the serving eNB sends execution command to UE.

2.4.2. Handover Execution

In this part the UE remove from present serving cell and start synchronization with new serving cell (actually with the target eNB). In this step the QoS may be degraded for the very short time of interval, between UE execute the handover command form serving eNB to the time target eNB receives the confirmation from the UE[40].

2.4.3. Handover Completion

The handover procedure is complete, when Serving Gateway (SGW) (i.e., this gateway is responsible of handovers between eNBs and also monitoring and maintaining the context information in LTE) transfer or switched data from serving eNB to target eNB [3, p. 45]. After that target eNB starts transmit data to UE through downlink data path.

2.5. Measurements for Handover in LTE-A

There are many measurements are used in LTE-A. Following are some important measurements used in proposed handover schemes.

2.5.1. Reference Signal Received Power (RSRP)

RSRP is defined as the linear average received power by the UE (or any receiver) from the reference signal resources elements over desired bandwidth (i.e., 5MHz, 10MHz and 20MHz). In LTE-A, Reference Signal Received Power (RSRP) is used in handover and cell reselection decisions. The measurement unit of RSRP is dBm

(Power referred on non-linear scale as one milliwatt) and it is measured by UE within measurement bandwidth over the cell-specific Reference Signal (RS) and over a measurement period[42]. In handover, RSRP is basically used to determining the best cell on downing link radio interference and used this cell as serving cell for handover procedure in LTE-A [43]. Moreover, the correlation exist between QoS and RSRP, for defining the correlation the RSRP ranges are categorised into three groups.

Group 1: -50dBm to -75dBm: excellent QoS's are expected in this range, this is only possible if there are not too many UE present in the cell for struggling to connect with cell for available bandwidth[43].

Group 2: -75dBm to -95dBm: the QoS slightly degraded in this range for example 30% to 50% overall throughput will decline in this range[43]

Group 3: -95dBm to -108dBm: in this range the QoS are not acceptable and when it reaches between -100dBm to -108dBm, the throughput almost go to zero[42]. In this range the call dropping probability is high and handover procedure is initiated.

Measured RSRP	*Measured RSRQ*	*Signal Strength/Quality*
−44dBm to-80dBm	-3dBm to-9dBm	Excellent
-81dBm to-90dBm	-10dBm to-12dBm	Good
-91dBm to-110dBm	-13dBm to-14dBm	Mid Cell
−111dBm to More	-15dBm to More	Cell edge

Table 1 Different Ranges RSRP and RSRQ (c.f., [42] [43]

2.5.2. Received Signal Strength Indicators (RSSI)

The received single power indication is used to indicate the total power received, that also include the interference form the adjacent cells and other sources like co-channel interference between serving and non-serving cell, thermal noise etc. it is also used in measuring the RSRQ. RSSI is not directly reported by UE, it is computed by RSRP and RSRQ. The general formula used for RSSI is given below; [49] [44]

$$RSSI = Noise + Serving\ Cell\ Power + Interference\ Power$$

2.5.3. Reference Signal Received Quality (RSRQ)

RSRQ is similar to RSRP because it is used in handover and cell reselection decision, where the RSRP alone is not sufficient to decide. So, the main purpose of RSRQ is determining the best cell for LTE radio connections. Normally it is measured in decibel (dB) on logarithmic scale [50, p. 251]. The better value of RSRQ shows the better signal quality in cell as compare with the interference generated by other adjacent cells. In additions, RSRQ is also providing the ranking between different cells on the basis of their reference signal strength that is helpful in handover decisions [49]. RSRQ is expressed in negative because the reference signal power is always smaller than the overall power received. The RSRQ is better, if it is close to '0' and it became worst if it had big difference from '0'. For example the -3dB of RSRQ is better than -10dB of RSRQ. It means at -3dB the transmission speed is very high and at -10 it is very low. So for improvements of cell signal strength, there is need of improvements in RSRP and RSRQ. Almost in all places, there is only one cell that dominant to other cell, whose RSRP and RSRQ are very high. So it means the RSRP of dominant cell is -50dBm and RSRQ is -3dB. So if there are two cell exist in any network, who has high signal strength, it means the RSRP of both cell is high and RSRQ is may be very low (about -8dB) because of signal interference with each other[50]. The formula of RSRQ is [49];

$$RSRQ = \frac{N * RSRP}{RSSI}$$

Where ‘N’ is presenting to total number of Resource Blocks (RB) (i.e.,the smallest unit of resources that allocate to users in downlink transmission in LTE)

2.5.4. Signal Interference plus Noise Ratio (SINR)

On basis of RB, UE measured the SINR on each RB. This value is related to Channel Quality Indicator (CQI) value in LTE-A. Actually UE measured SINR is converted into CQI, that CQI value sends/report to eNoB, where is used to decide the most suitable MCS for data transmission in particular RB [49].

2.6. Handover Parameter

The handover parameters mostly depend on the handover procedure and handover scheme. These parameters are playing key role to improve the QoS of network. In LTE-A, triggering of handover event is took place along with other parameters. The detail is given below:

2.6.1. Handover Initiations Threshold Level of Reference Signal Power

This is one of important parameter of LTE-A handover. Reference signal power is referred to RSRP and RSRQ in this parameter. So there is a threshold level of power, once the received signal power is decreased or cross the threshold level, the handover process will start. The threshold level is set by mobile operator, and in research different authors used different threshold level, depends on the situation and scenario. As mentioned above the signal strength is good at -75dBm of RSRP and it is poorest after -108dBm but the reception is present till -130dBm [45]. So the QoS start degrading after -90dBm, therefore the threshold level may be set after this value to save the resources and make successful handover.

2.6.2. Hysteresis Margin

The Hysteresis Margin (HM) is also refereed as Handover Margin. Usually it’s a constant value that is set by network provider. It is used to make delay in handover decisions for avoiding the ping pong effect. Now, the modification of HM is also introduced named as Adaptive Hysteresis Margin (AHM). Adaptive Hysteresis Margin is based on actual HM value [51] [52], it is changing with movement of UE.

When UE is get closer to cell boundaries the HM is decreasing and when it is closed to central location of cell, it is increasing.

The main reason of introducing the HM in handover is to reduce or avoid the ping-pong effect. Ping-pong effect is occurred during a hard handover, when a call handed over form serving eNB to target eNB, but quickly handed back to serving cell again. The HM is inversely proportional to ping-pong effect, it means for big value of HM, the ping-pong effect will decrease. The value of HM should be a reasonable, because for big values the UE take long time to handover, it means delay will increase. Therefore, the UE causes extra interferences to neighbouring cells due to poor quality link during the delay. So the value of HM is fairly important for hard handover [53, p. 111].

2.6.3. Time to Trigger

Once the handover requirements are fulfilled, Time to Trigger (TTT) commands is initiated. This parameter is important to decrease the unnecessary handovers and also efficiently avoid the pin-pong effects. Also, this parameter causes the handover delay that increase the probability of handover failure. Once the TTT is initiated, it means, it trigger the measurement reports. The values of TTT are 0, 40, 80, 100, 128, 160, 256, 320, 480, 512, 640, 1024, 1280, 2560, 5120ms [54].

2.7. Technical Specification of LTE-A Wireless Networks

2.7.1. LTE-A Network Architecture

The radio architecture of LTE-A is shown in Fig. 6. The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) is official name of 3GPP's radio access network of LTE-A. The radio technology Wideband Code Division Multiple Access (WCDMA) is replaced with Orthogonal Frequency Division Multiple Access (OFDMA) to attain the greater bandwidth and speed [55]. Furthermore, the LTE-A network architecture consists of three elements: enhanced-NodeB (eNB) (previously known as base station in wireless network), Mobile Management Entity (MME), and serving gateway/packet data network gateway (SGW/PDNGW). Moreover, eNB performs packet scheduling and handover functions, MME's responsibility, UE (user equipment) mobility and identity, S-GW and P-GW are responsible to terminate the interface towards E-UTRAN and packet data network respectively [56] [57].

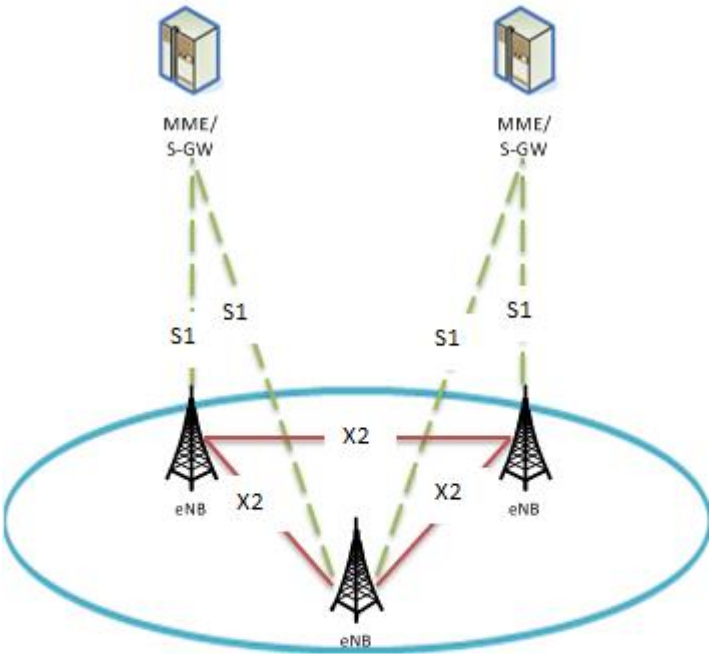

Fig. 6 LTE-A Overall Architecture (c.f., [57] [55])

As well, two radio interfaces X1 and S1 are part of LTE-A network architecture. Moreover, these interfaces are used in handover procedure with different purposes [55].

2.7.1.1. Evolved Node B (eNodeB/eNB)

eNodeB or eNB is abbreviation of evolved node B. It is used in 4G networks instead of Base Station (BS) in previous 3G networks. Actually the eNB is more efficient than 3G base stations. eNB controls all radio related function and it provides bridging between UE and EPC [58]. The protocols terminated at the eNB that are used in access link. Moreover, cipering/deciphering and IP header compression/decompression done at eNB.

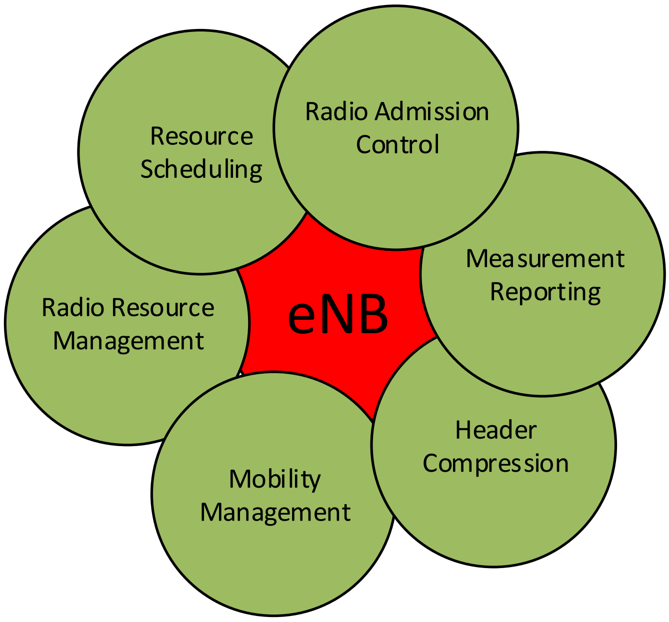

Fig. 7 Main Function of eNB (c.f., [58])

Therefore, eNB is considered as complex node, who is also responsible and handling communication between several devices in the cell, also perform the handover decision and radio resource management activities. The Radio Network Controller (RNC) is not present in LTE standard of 4G and 5G network, the RNC functionality is now performed by eNB [59]. In GSM, the traditional base station was controlled by RNC, but now it is removed from the architecture, that make it simple and allows lower response time.

2.7.1.2. User Equipment

User Equipment (UE) is any device that used for communication by end users. In GSM, Mobile Station (MS) termed were used for UE. It is replaced in 4G network with UE, because the end user devices are having big variety, that include any device such as iPad, smart phone, smart tabs, or computer etc. [58].

UE is divided into two main parts; terminal equipment (mobile handset/device) and Universal Subscriber Identity Module (USIM). USIM is an application that contain information of users (normally a unique security key for authentication and identification). This USIM application is placed into Universal Integrated Circuit Card (UICC). This whole part is in short called sim card[60] .

This sim card is placed into terminal equipment, and it is providing the connectivity of terminal equipment to mobile networks. In 4G and 5G mobile networks, the responsibilities of UE is also increased, mainly the handover is assisted by UE, because continuously UE sends the feedback report to the connecting eNB.

2.7.2. Orthogonal Frequency Division Multiple Access (OFDMA)

OFDMA is a multicarrier scheme that allocates radio resources to multiple users. OFDMA based on Orthogonal Frequency Division Multiplexing (OFDM). In LTE, ODFM splits the carrier frequency bandwidth into many small subcarriers spaced at 15 kHz. Moreover, each subcarrier modulated using the QPSK, 16-QAM or 64-QAM digital modulation formats. OFDMA responsible to assigns the bandwidth to each user according to their requirement for transmission. Furthermore, 1.4, 3, 5, 10, 15 and 20MHz scalable radio frequency channel bandwidths used in LTE-A [61]

2.7.3. Frame format

Frequency Division Duplex (FDD) and Time Division Duplex (TDD) are two types of frames, considered in LTE-A. The frame format of two types will discuss below.

2.7.3.1. Type1: FDD

LTE-A Type-1 frame structure is shown in following Fig. 8. The 10ms frame divided into ten equally subframes (1ms per subframe). One subframe further divided into two equally size time slots (0.5ms per slot). In FDD, ten subframes are available for downlink and ten subframes are available for uplink transmission in each 10ms interval of time [61] [56]

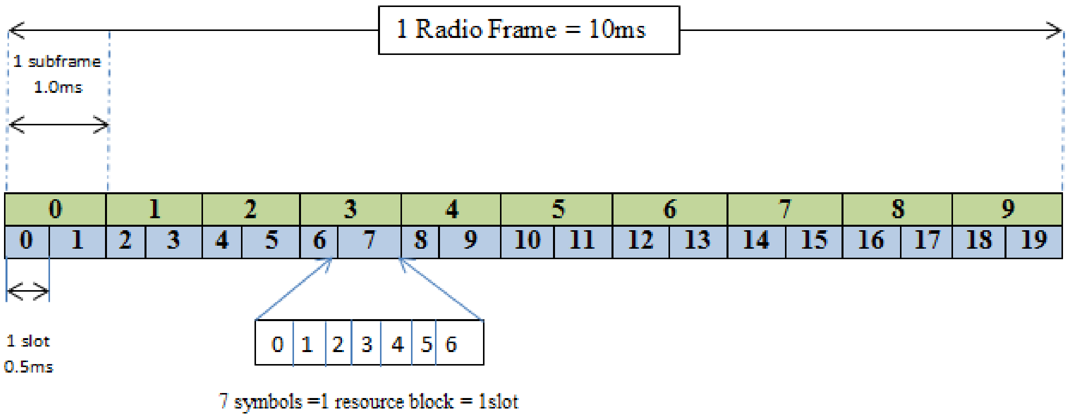

Fig. 8 LTE-A type-1 Frame Structure (c.f., [56])

2.7.3.2. Type 2: TDD

LTE-A Type-2 frame structure is shown in following Fig.9. Where 10ms radio frame is divided into two half frame of 5ms. Furthermore, each 5ms half frame is divided into eight slot and three special fields called Downlink Pilot Time Slot (DwPTS), Guard Period (GP) and Uplink Pilot Time Slot (UpPTS). Type 2 frames contain two half frames, and each one is carrying the DwPTS, GP, UpPTS. Moreover, depending on the switching time, at least one subframe is carrying this special field. e.g. if the switch time is 10ms then switching information will occur only in subframe one, and if its 5ms, then it will occur in both frames. Subframes 0 and 5 and DwPTS are always reserved for downlink transmission. UpPTS and the subframe immediately following UpPTS are reserved for uplink transmission [61] [56]

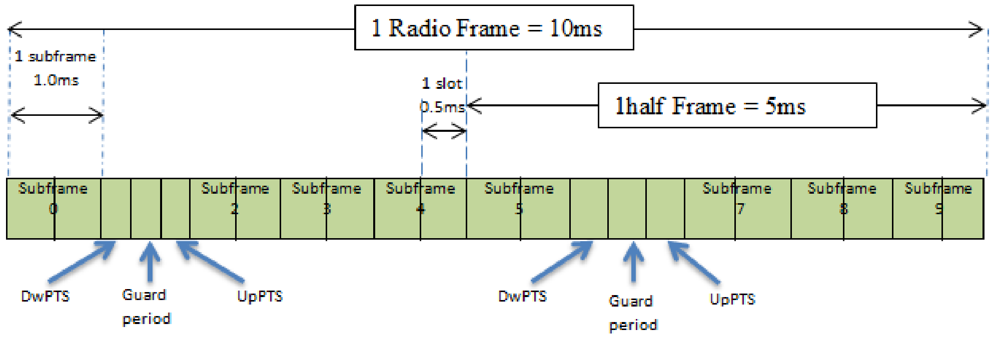

Fig. 9 LTE-A type 2 Frame Structure(c.f., [56])

Summary of Chapter 2

Chapter 2 consists of two parts; the first part encloses the history and background of wireless networks. Also, this part gives detailed overview about how different techniques and technologies of telecommunications mitigated from 1st generation of mobile to 5th generation of mobiles. Moreover, second part of chapter 2 having details of handover in LTE-A, that is helpful in deciding the proposed handover techniques. This part holds technical information of measurements reports, handover parts and its parameters. Measurements reports in LTE-A are RSRP, RSRQ, RSSI and SINR discussed in detail to determine reliable solution of unnecessary handovers in future network. The handover parameters such as threshold level, time to trigger, handover margin and hysteresis values are discussed in details to find solution how to overcome the problems of unnecessary number of handover in future and existing networks. Chapter 2 is one of important chapter of this thesis, additionally cover all technical aspect of LTE-A system along with the network architecture, and OFDM frame format that provides help to perform numerical calculations of proposed handover schemes to reduced number of unnecessary handovers.

Chapter 3: An Overview of Coordinated Multipoint (CoMP) Technique

3. Introduction

In LTE-advanced the coordinated multipoint transmission/reception is used to improve the coverage of high data rates and decrease the cell edge interference and improve the throughput in high and low load scenarios.

3.1. CoMP Categories

Coordinated multipoint is categorised into Joint Transmission (JT) and coordinated scheduling and beamforming (CS/CB). The latest and advanced category is called dynamic selection.

3.1.1. Joint Transmission (JT)

Joint Transmission (JT) is a CoMP category, in which single UE receives data from multiple eNBs. The data is available coherently or non-coherently to improve the received signal quality and throughput of the UE [13] [62] [63]. Coherently transmission in JT is based on Channel State Information (CSI) feedback of two or more eNBs and that is helpful for performing MIMO transmission from the corresponding antennas and in "Non-coherent JT may use techniques like single-frequency network (SFN) or cyclic delay diversity (CDD) schemes, which target diversity gains and also enable increased transmit power to the UE"

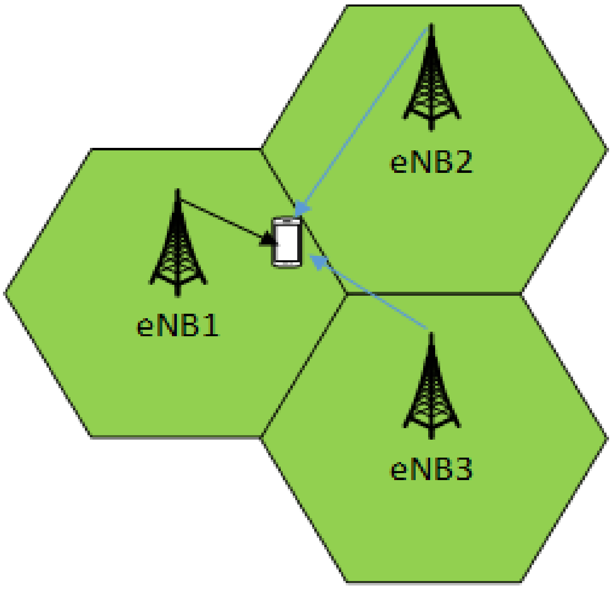

Fig. 10 Joint Transmission(c.f., [12])

Actually, JT is helping at cell edge where it improves performance of network by converting the interference signal of neighbouring cells to desired or useful signal. The cell edge interference is worst in presence of dense deployment of transmission points (eNBs) in homogeneous networks and in presence of low power nodes such as femtocells in heterogeneous networks. In such situations, JT is effective and good solution because the interference UE received from adjacent cells converting into desired signal in presence of JT.

3.1.2. Coordinated Scheduling and Beam Forming (CS/CB)

Coordinated Scheduling and Beam Forming (CS/CB) is a CoMP technique, where UE received data from serving cell only, but multiple transmission point (cells) involved in the user scheduling/ beamforming decisions. The coordination takes place among the cells that are part of CoMP cooperating set [62] [63].

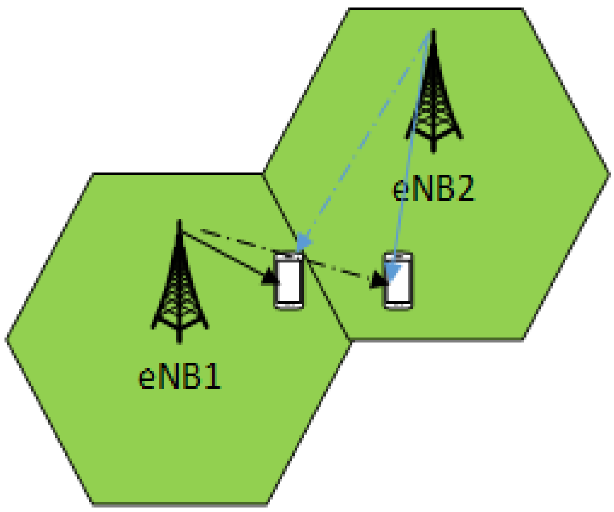

Fig. 11 Coordinated Scheduling and Beam forming (c.f., [12])

The concept of Coordinated Beamforming (CB) was used in 1990s to find out the solution of Signal to Interference plus Noise Ratio (SINR), that time the beamforming coefficient and power levels were calculated to achieve different levels of SINRs. On the other hand, Coordinated Scheduling (CS) is bit newer idea, in which the whole network is divided into clusters and with help of centralised scheduling determine which transmission point will use which time slots to transmit data to UE. In LTE, the both concepts of CS and CB are merged and used to reduce the multicell interference [13].

3.1.3. Dynamic Cell Selection

This is simple CoMP technique, where the cell is serving to specific UE. Moreover, the serving cell selection may be changed according to channel state information and wireless resources availability on the sub frame level (after every millisecond) [13]

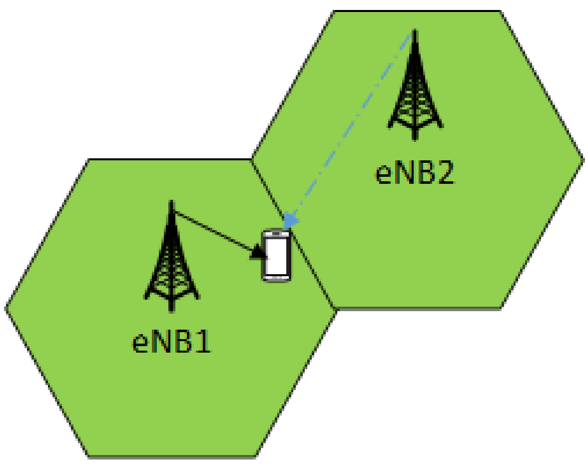

Fig. 12 Dynamic Cell Selection (c.f., [12])

3.2. CoMP Sets

CoMP consists of different set of eNB that use to provide coordination among different base stations. Even the fully CoMP is part of LTE-A Release 11, but CoMP set are including in Release 9 of long term evolution specification. The details of these sets are as follow:

3.2.1. CoMP Cooperative Set (CCS)

CCS is set of geographical separated points (micro or macrocell) that directly or indirectly participate in PDSCH (Physical downlink share channel) transmission to UE. Moreover, this set may or may not be transparent to the UE [62]

3.2.2. CoMP Transmission Point Set (CTP)

CTP is set of points that actively transmitting PDSCH to UE. Furthermore, this set is subset of CCS. This set is behaved different for JT, CS/CB and dynamic selection. For JT the transmission points are the points in CCS, for CS/CB only single transmission point at every subframe. This transmission dynamically changes in the CCS [62]

3.2.3. CoMP Measurement Set

The measurement set is set of cells based on the reporting/feedback information related to the link received from UE on basis of Channel State Information (CSI). The size of CoMP measurement set and CCS may be same, depends on the scenarios. [62]

3.3. Deployment Scenarios

CoMP considers four different scenarios of deployment. These deployment scenarios are mainly categorised into two types; Homogeneous and heterogeneous. Furthermore, the two types are subdivided into following four scenarios [13] [64]

3.3.1. Scenario 1

CoMP deployment scenario 1 is also known as homogeneous macro network with intra-site CoMP, where a single eNB provide the coordination between cells of same site. This is most practical scenario of CoMP as compare with other scenario and this scenario practically exists because there is no need for external connections between sites [13]. Scenario 1 is used in present research to find the solution cell interference at cell edge. For this purpose 7 homogeneous cells are considered, details is given in chapter 4 and chapter 5.

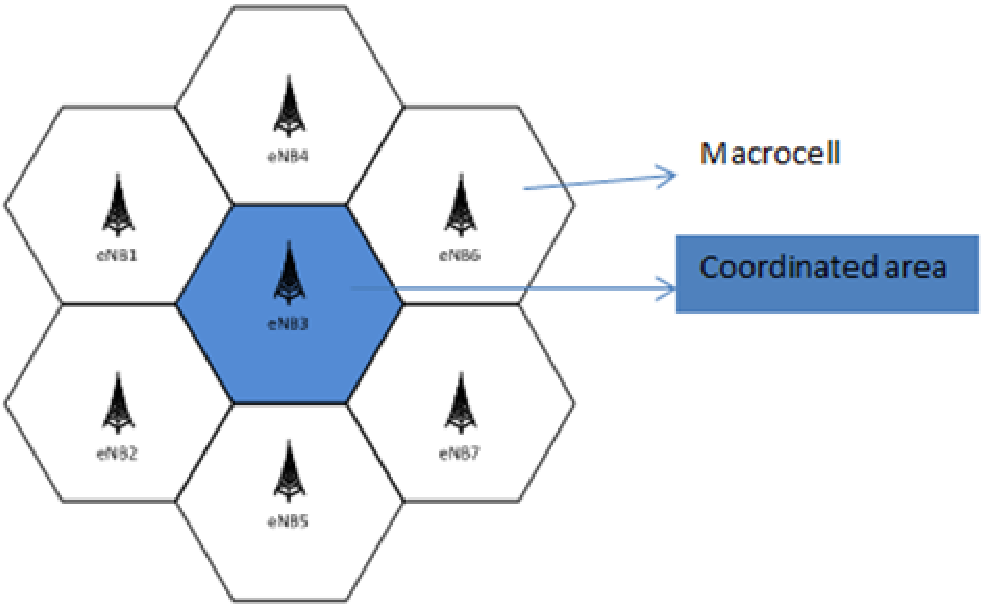

Fig. 13 Homogeneous macro network with intra-site CoMP (c.f., [12] [13])

3.3.2. Scenario 2

CoMP deployment scenario 2 is also known as homogeneous macro network with inter-site CoMP. This scenario is extension of scenario 1 and includes the multiple cells on different sites to provide the coordination between cells. This coordination may take place between high power remote heads and eNBs. The main advantage of this scenario is the coordination area increased [13] [12].

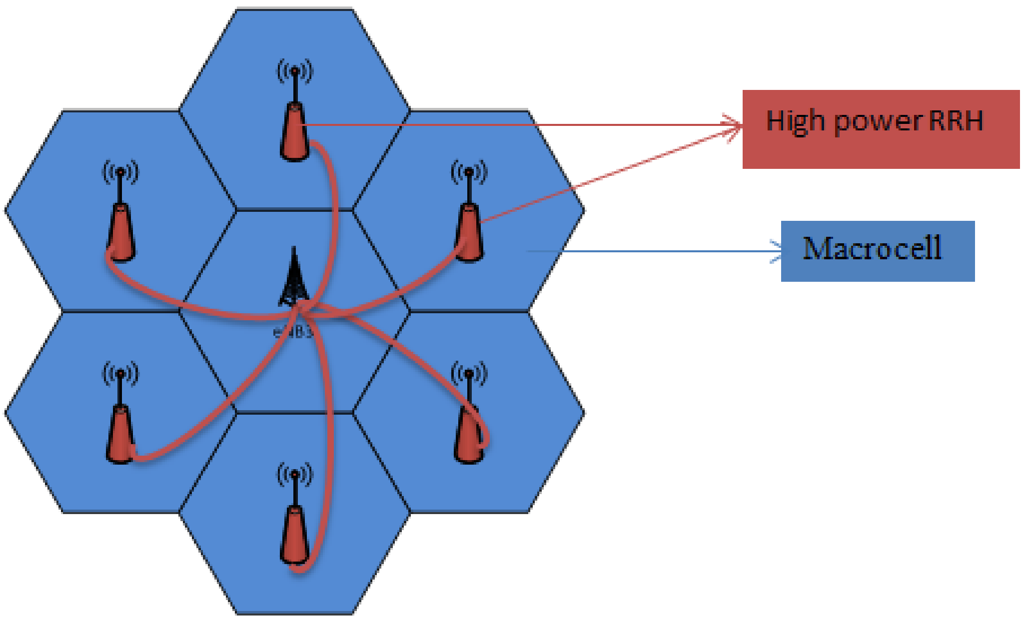

Fig. 14 Homogeneous macro network with inter-site CoMP (c.f., [12] [13])

3.3.3. Scenario 3

CoMP deployment scenario 3 is also known as heterogeneous network with low power remote heads (picocells) within the macrocell coverage area. A number of picocells connected to eNB are deployed in macrocell coverage. The interference may increase because of many picocells. To overcome these challenges eICIC introduced in latest release of LTE-A [12] [13]

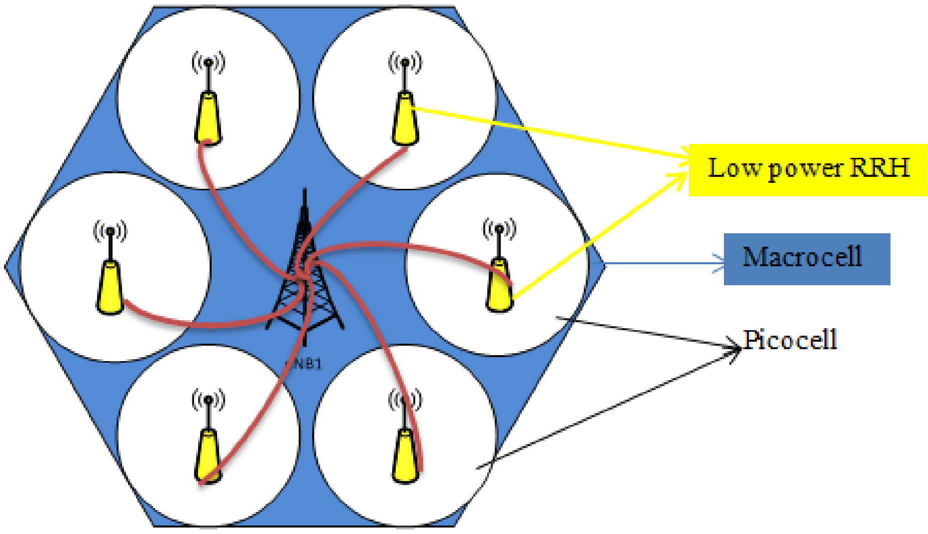

Fig. 15 Heterogeneous network with low power remote heads (picocells) (c.f., [12] [13])

3.3.4. Scenario 4

CoMP deployment scenario 4 is also known as heterogeneous with lower power remote radio heads (RRH) within the macrocell coverage area. In this deployment scenario the remote area heads have same physical identity cells as macrocell. The main difference between scenario 3 and 4 is, no new cell is formed by RRHs, this difference results in distinct control design and mobility management [12] [13]

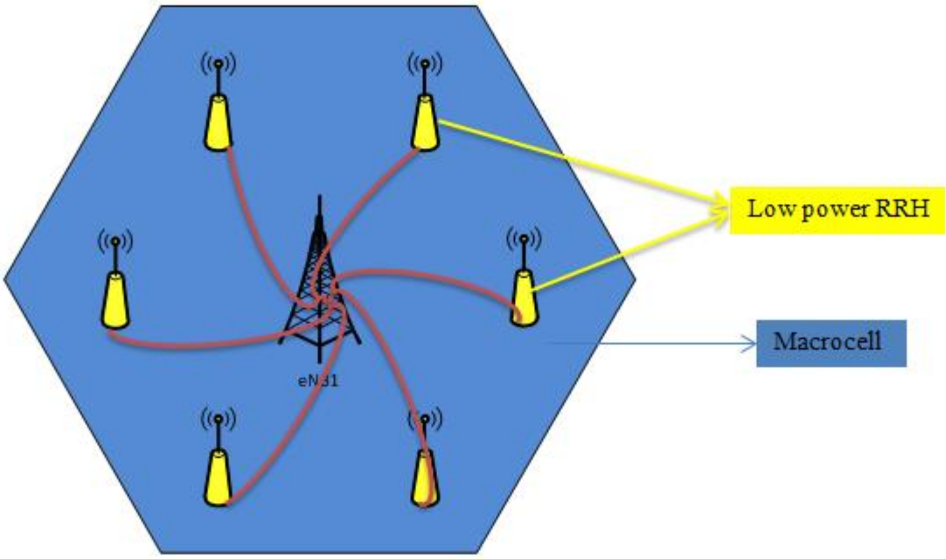

Fig. 16 Heterogeneous with lower power remote radio heads (RRH) (c.f., [12] [13])

After observing detailed overview of Coordinated Multipoint technique (CoMP), following is detailed example of this technique, how it is working in real network scenarios.

3.4.An Example of CoMP Technique (Scenario 1)

For more details and understanding of CoMP-JT technique for homogeneous networks consider following example. Consider the network is consisting on 14 cells and each cell has only one eNB. Follow following steps to analyse CoMP full operation in LTE-A.

In step 1, UE's selection of serving eNB is important. The selection of serving cell is based on the value of RSRP. UE always attached with eNB having highest RSRP vale or instructed by previous cell. In example, let's suppose eNB7 is a serving cell, who has highest RSRP based on measurement report feedback by UE to serving cell. The important consideration is here; at a time single UE has only one eNB and that is responsible of selection, reselection and handover decisions [65]

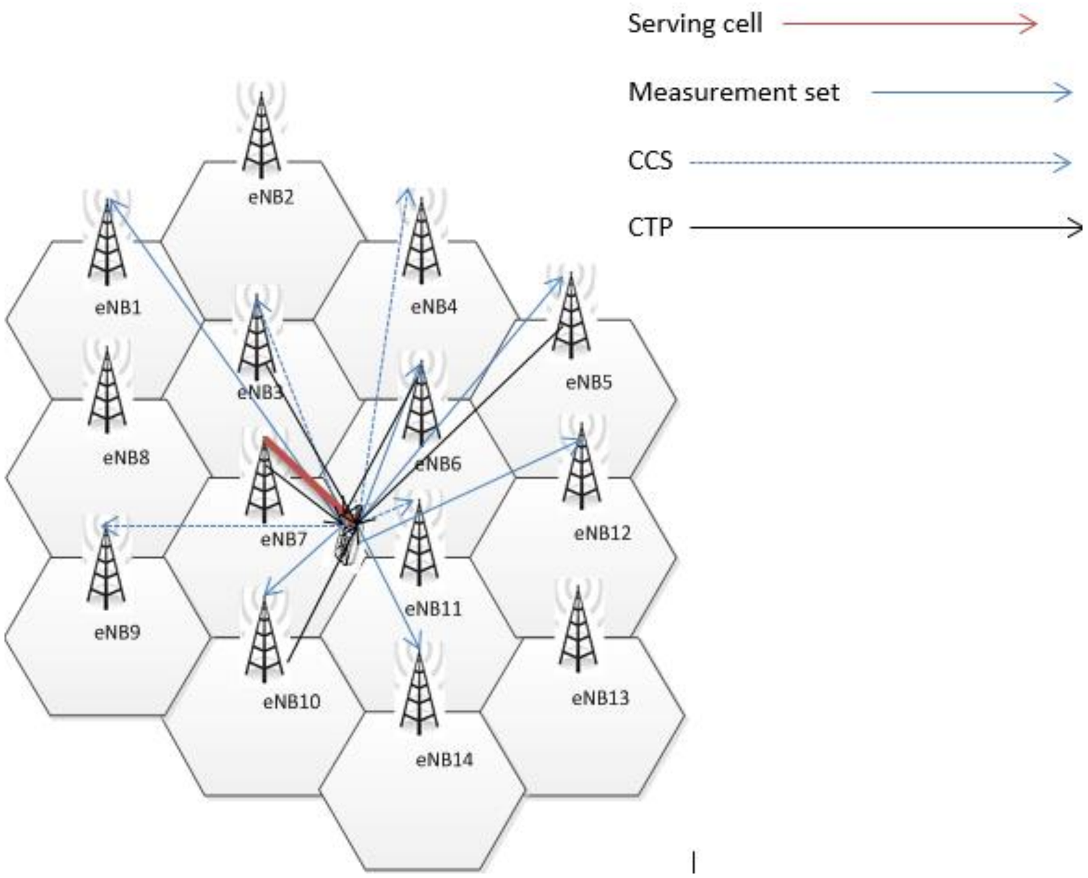

Fig. 17 Example of CoMP Technique

Step 2 is consisting the information of triggering CoMP or not. Actually, when UE is experienced low RSRP value than threshold level (i.e., a value of RSRP set by network provider) a CoMP is triggered and serving eNB start communication with adjacent eNBs for jointly transmit data to UE (i.e., the detailed scenarios, and techniques are discussed above for this step). For this purpose UE collect all information regarding measurement reports and feedback to serving eNB.

In step 3, serving eNB maintain measurement set on basis of received report from UE. The number of elements of measurement set are decided by network operator. In example, consider the size of measurement set is 10. Therefore the measurement set is consisting on { 1,3,4,5,6,7,9,10,11,12} eNBs, they are having highest RSRP values.

Step 4 related with selection of CoMP Cooperative Set (CCS) that is directly or indirectly participating in PDSCH (i.e., Physical downlink shared channel user to transmit downlink data to UE) transmission to UE and may be transparent to UE. The selection of cells depends on RSRP value. The CCS is subset of measurement set and its size defined by operator. Assume size of CCS is 5 and in above scenario we have CCS as {3, 4, 7, 9, 11}

Finally the selection of CoMP Transmission Points (CTP) actively transmitting the PDSCH to UE. And CTP is subset of CCS and size is also determined by the operator or service provider. Assume size of CTP is 3. In above scenario we have CTP as {3, 7, 9}. So 3, 7 and 9 eNB are cooperative nodes, they are sending data directly to UE in COMP mode. For transferring the data to UE from multiple eNBs, there are different scheduling types are available, some of them are explained below.

3.5. CoMP Scheduling Types

In cellular networks the scheduling plays vital role in allocation of radio resources, the termed scheduling is refereed to distribution of radio resources such as time, energy/power and frequency to UE in mobile networks. The performance of networks is heavily depended on the scheduling, how to effectively the available resources distributed among the UE. Therefore, in CoMP there are two types of scheduling are considered. [69, 70]:

- Centralized
- Distributed

3.5.1. Centralized

In centralised scheduling, there is a centre node called resource coordinator (RC), who is responsible of allocation of radio resources among UEs. All neighbouring eNBs share their information with RC, which is normally inner macro-cell having same distance with all neighbouring cells. The neighbouring cells, who are participants of CoMP, are sharing information with RC [66]. So RC decide the allocation of resources between different UEs. All neighbouring eNBs are connected through X2 interface. This type of scheduling is normally avoided in CoMP, because of IP backhauled delay, and inter-culster interference [66].

3.5.2. Distributed

In distributed scheduling, there is X2 interface is present between two eNBs, so each eNB share information with neighbouring eNB. Therefore, all eNB are connected with each other through X2 interface, so any eNB can participate for CoMP. It is easy to implement as compare with the centralised distribution [66].

3.6. CoMP Resource Scheduling Algorithms

There are different algorithms are proposed for CoMP resource scheduling. The main purpose of designing these algorithms are to avoid the cell edge interference and increased throughput at the cell edge users. Some of algorithms are;

- Maximum CQI Scheduler
- Proportional Fair Based Scheduler

3.6.1. Maximum CQI Schedular

CQI is abbrivated of Channel Quality Indicator, as name indicates, it is realted with the quality of channel , how good or bad is quality of channel carrying information. In LTE there are CQI values ranges from 0 to 30. Where ‘0’ is used for worst channel conditions and ‘30’ is used for good or best channel conditions. So Maximum CQI sheduler is determining the UEs, they have best quality condtions [67]. The MC scheduler sorts CQI reported by all registered UEs in a CoMP cooperating set (i.e., disscusssed in last section) and allocates all available RBs to the qualified UEs to reach the maximum system throughput. Moreover, our main concern is users that are present on cell edge, where the CQI is normally worst, so according this schduling the cell-edge user are ignored because they have bad channel conditions.

3.6.2. Propotional Fair Based Scheduling

Proportional Fair Based Scheduling (PFS) algorithms are widely accepted in research because they are providing the balance between the throughput and user fairness by diversity gain [measured in decibel, it is refereed to signal to interference ratio or it is referred to transmission power reduced due to diversity schemes]. The main purpose of PFS is to allocate fairly the resources to all UEs to increase the maximum throughput [68].

To understand the PFS, consider there are N users are connected with eNB, and every user send some data to N locations. Moreover, every user has different transmission rate. A RF scheduler is located on eNB, and received continuously the channel conditions of every users after specific time slots. In Case of LTE-CoMP this feedback process is repeated on every time slot. If the channel measurement feedback delay is relatively small compared to the channel rate variation, the scheduler has a good enough estimate of all the users' channel condition when it schedules a packet to be transmitted to the user. Since channel condition varies independently among different users, PF exploits user diversity by selecting the user with the best condition to transmit during different time slots. This approach can increase system throughput substantially compared to a round-robin scheduler [69] [70].

Summary of Chapter 3

Chapter 3 contains all relevant information about coordinated multipoint (CoMP) technique of LTE-A system. That information is very useful for proposed handover schemes to decide the right category of CoMP technique such as Joint Transmission (JT), Beamforming Scheduling (BS) and dynamic selection. The details of these categories are presented in this chapter. Moreover, the discussion of CoMP sets along with example gives clear picture of this technique. In this chapter the scheduling types and algorithms are also discussed that used in proposed schemes.

Chapter 4: Downlink LTE-A System Level Simulator

4. Introduction

There are many programme and procedures used to measure the performance of wireless networks in academic research and as well as for industrial research. These are includes theoretical analysis, test bed and computer simulations. Theoretical analysis are not easy to implement because they are based on detailed description of research. There are many steps involved to get final accurate results such as; origin, meaning, usefulness, degree of generalisability and testability of theory [71]. Test bed includes the information of hardware, software and networking components along with labour and considerable finance. At the end the test bed results are not easy to evaluate, they are difficult to understand [72]. Therefore, computer simulation is used in current research because it is easy to understand and easy to implements as compare with theoretical procedure and test beds. The complexity of intermediate steps are not required for computer simulations like in the case of handovers, need general information about the handover along with proposed algorithms to evaluate the schemes. In addition, computer simulation is widely used in wireless networks to evaluate the performance of networks. It is less expensive because the large wireless networks behaviour can check with help of computer simulation without implementation of physical infrastructure.

There are large variety of computer simulators are available for implementation of proposed handover algorithms such as, LTE-Sim [18], MathWorks LTE System Toolbox [73], SimuLTE using OMNeT++ [74], Vienna LTE-A Simulators [20], Ns3 LTE Simulator [19] and LTE-A System Level Downlink Simulator [22] [21]. LTE-Sim and SimuLTE are open source simulator and explained many features of LTE-A but they are not fully support to CoMP handover technique. Similarly, Vienna LTE-A and LTE System Toolbox are licenced simulator and required good background of Matlab to implement the algorithms but the functionality of CoMP is technique is not address in these simulators as well. Therefore in present research LTE-A System Level Downlink Simulator [22] [21] is used, because many related work of present research is already done in this simulator and it is fully support to handover mechanism of LTE-A.

4.1. Downlink LTE-A System Level Simulator

The simulator is based on packet scheduling and support to scheduling algorithms such as; Round Robin, maximum rate, and proportional fair scheduling. Moreover, the simulator is support to different traffic models such as; web browsing traffic model (i.e., modelling of traffic used for web browser consists of main objects and embedded objects) and constant stream model (i.e., UEs received sequence of packets constantly at regular time interval). Furthermore, LTE-A System Level Downlink Simulator consist of following models;

4.1.1. System Modelling

In LTE-A, the smallest unit of resources that allocate to users in downlink transmission is called Resource Block (RB) or Physical Resource Block (PRB). In time domain it consist of 7 OFDM symbols and required o.5ms duration to transmit these symbols and in frequency domain it consist on 12 sub-carrier and each sub-carrier has 15kHz spacing. Therefore each PRB gives 180 kHz bandwidth (12 * 15 kHz). These specification are taken from the 3GPP technical report [75]. Moreover, A system consists of 7 hexagonal cells, each cell has 100m radius and users are randomly distributed over cell with in cell boundaries [21]. The rest of assumptions and simulation's input data list are given in Chapter 4 and 5.

4.1.2. Mobility Modelling

Initially UEs are assigned a random directions and having constant speed with in the cell. After some time 't' the location of user 'i' location is determined with help of following equation [22] [21].

$$loc_i(t) = loc_i(t-1) + (v_i(t-1) \times dir_i(t-1))$$

Where $loc_i(t)$ is the location of user 'i' at time't' and $v_i(t-1) and\ dir_i\ (t-1)$ are speed and direction of user 'i' at time (t-1) respectively. Moreover at boundary of cell wrap-around function [76] is implemented to ensure the users always stays at the coverage area of cell. To understand the wrap-around function [77] consider following example.

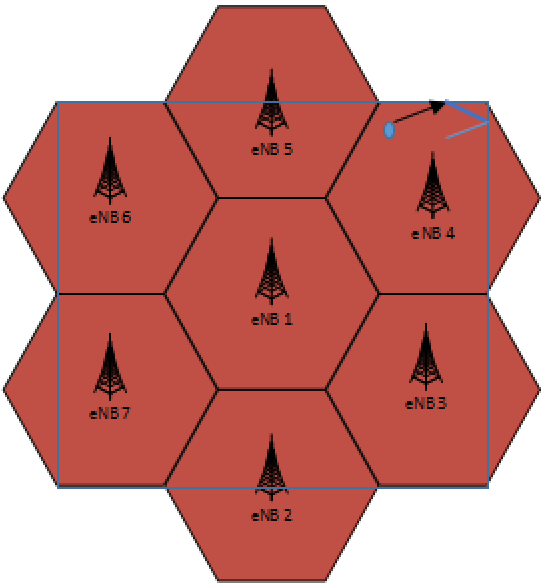

Fig. 18: Example of Wrap-around Function (c.f., **[77]**)

In above figure the blue lines shows the system's boundary. Where a user in eNB4 is moving to the edge of boundary on right top cornor, so by using wrap-around function the user is reflected and keep in the eNB4 coverage area. This method is proposed in simulatorpt to make sure the users are always reside in the simualation area [77].

4.1.3. Radio Propagation Modelling

During propagating radio signal from transmitter to receiver the signal quality is effected at receiver end. The path loss, multipath fading and shadow fading are main components of channel gain that effect the signal strengths [21]. In following the detail of these components is given.

4.1.3.1. Path Loss

For path loss calculations Hata model is used and given below [21] .

$$PiL = 46.3 + 33.9\log(f) - 13.82\log(G_{eNB}) - a(G_{UE})$$
$$+ (44.9 - 6.55\log(G_{eNB}))\log(d_i)$$

Where $a(G_{UE}) = (1.11log(f) - 0.7)G_{UE} - (1.56log(f)) - 0.8)$

‘d_i’ is UE’s distance from eNB in km and ‘G_{eNB}’ is eNB (transmitter) antenna gain, and ‘G_{UE}’ is UE (Receiver) antenna gain

4.1.3.2. Shadow Fading

These are signal strengths variations caused by diffraction and reflection from hurdles such as rocks, high building and tress. In this simulator the shadow fading is calculated with 0 dB mean and a 8dB standard deviation using Gaussian lognormal distribution [78]. Following expression are used to find out the shadow fading [21].

$$\xi_i(t) = \exp\left(\frac{-v_i(t-1)}{d_0}\right)\rho_i(t-1) \times \xi_i(t-1) + \sigma \times \left(\sqrt{1 - \exp\left(\frac{-v_i(t-1)}{d_0}\right)}\right) \times G(t-1)$$

Where $-v_i(t-1)$ is ith user’s speed at time‘t-1’, σ is standard deviation and $G(t-1)$ is random variable of Gaussian at time‘t-1’

4.1.3.3. Signal to Interference plus Noise Ratio (SINR)

For measuring the quality of wireless communication connection the Signal to Interference plus Noise Ratio (SINR) is commonly considered. On each Resource Block SINR value is varied experienced by UE, It is happening in cellular networks because of time–selective fading nature of radio signals [79] . In present simulator the instantaneous SINR ($\gamma_{i,j}(t)$ at time 't' for user 'i' for PRB 'j') is calculated with help of following expression [21].

$$\gamma_{i,j}(t) = \frac{P_{total} * gain_{i,j}(t)}{PRB_{max}(ICI + N_0)}$$

Where P_{total} is total power transmitted by eNB, PRB_{max} are maximum available physical resource blocks and where gain is

$$gain_{i,j}(t) = 10^{\frac{pli(t)}{10}} * 10^{\frac{\xi i(t)}{10}} * 10^{\frac{mpathi,f(t)}{10}}$$

Where $mpath_{i,j}(t)$ is multipath fading of user 'i' on 'j' PRB. Similarly $pli(t)$ and $\xi i(t)$ are path loss and shadow fading of user 'i' at time 't' respectively.

4.1.3.4. Reference Signal Received Power (RSRP)

RSRP is one of important measurement, the handover decision in this thesis is based on these measurements. So the value of RSRP is varied for user on each time slots on each RB. So the RSRP is computed as;

$$RSRP_{i,j}(t) = P_{total} * gain_{i,j}(t)$$

$$\overline{RSRP_{i,}}(t) = \frac{\sum_{j=1}^{J} RSRP_{i,j}(t)}{J}$$

Where $RSRP_{i,j}(t)$ is RSRP value for user 'i' in time 't' on RB 'j' and $\overline{RSRP_{i}}(t)$ is average RSRP of user 'i' at time 't'.

4.1.3.5. Packet Scheduling

Packet scheduling is used to transmit data to users in the simulator. In which the fixed small sized time stamped packets are placed in the buffer located at eNB and they are transmitted on First-In-First-Out (FIFO) basis. In current research assume the buffer are full throughout the simulation. The packet delay is total time the each user packet in the buffer until it has been transmitted. And a packet is discarded if it will stay more than threshold in the buffer. Threshold level is defined the maximum time that a packet can stay in the eNB buffer and it depend on the traffic size and pattern [77] .

Summary of Chapter 4

Chapter 4 contains, the information of simulator that is used to simulate the results of proposed algorithms of handover schemes. The Chapter also contain the comparison of different simulators and why they are not useful in existing research. Moreover, system modelling, mobility modelling and radio propagation modelling are included in this chapter. They are helping in calculation of proposed schemes.

Chapter 5: An Efficient CoMP-based Handover Scheme for Next Generation Wireless Networks to Reduce Unnecessary Number of Handovers at the Cell Edge

5. Introduction

Coordinated Multipoint (CoMP) is an advanced technology of Long Term Evolution-Advance (LTE-A), which comprises many solutions such as Inter-Cell Interference and Intra-Cell Interference [11] [80] [81]. Moreover, it helps to mitigate the aforementioned interferences and increase the cell edge performance. To this end, the CoMP technique plays a vital role in current research towards the reduction of decisions for unnecessary handovers at the cell edge and the follow up improvement of network performance [65] [82].

The performance of evolving wireless networks highly depends on the mobility of users because the network site consists on many microcells (femtocell) and macrocells (eNB). In this context, a User Equipment (UE) carries out many times handover from the serving eNB to the target eNB and also attempts handover back to previous serving cell [83] [84] in short time intervals. Consequently, the Quality of

Services (QoS) are degraded because the resources are wasted and the probability of handover failure is increased due to a large number of unnecessary handovers. It also results in power dissipation of UE battery and lower the throughput gain [85].

The main focus of this research is to provide a new handover scheme in order to overcome the causes of unnecessary handovers by using the CoMP technique and reference signal measurements of eNB (Evolved Node B). In this research reference signal measurement are referred to Reference Signal Received Power (RSRP) that is the linear average received power by the UE and Reference Signal Received Quality (RSRQ) that indicates the quality of received signal.

5.1. Existing and Related Work

In wireless networks the values of handover hysteresis and handover margin (HOM) (i.e., two of handover triggers at the UE defined by the network) are mainly considered to reduce the number of unnecessary handovers. Therefore, in LTE-A these values are also widely used in handover algorithms and proposed schemes [65] [86]. In [87] authors presented the grouping algorithm based on adaptive hysteresis value (i.e., based on actual hysteresis value but changing with time). This algorithm consists of two steps, where the predefined threshold are defined for each step to move into next step. To avoid the unnecessary handovers, the algorithm is implemented on whole group without acknowledge the exact location of users, they made group only on the history of base station where users are currently attached. In such cases may be this algorithm avoid unnecessary handovers in some cases but the overheads are increased because this not necessary at a time, everyone in group required handover. In [85], authors have proposed method to control unnecessary handovers in heterogeneous network with dense deployment of small cells. In this method, a shortened candidate (UE) list is introduced on basis of UE actual distance and angle of movement from base station. The simulations results showed that when speed is considered, the proposed method has low probability of unnecessary handover as compare with conventional handover algorithms. Although authors discussed and presented good research work but they have ignored main issues such as load on the serving eNB and interference level at the cell edge in his results. These are main issues of future networks during handover decisions. Another handover scheme for microcell is presented in [88] based on hysteresis margin value to overcome the redundant handovers. For this purpose they calculated the position of

UE to set the hysteresis margin value. Although, the algorithm is much closed to traditional and conventional algorithms but it used good channel quality indicators values to defined the decision parameters. This algorithm is much closed to present research with addition of RSRP and RSRQ.

5.2. Proposed Handover Scheme

A proposed handover scheme of a wireless homogeneous network is presented in Fig. 19 consisting of 3 hexagonal macrocells (eNBs). The eNB's antenna is located at the centre of cell and they are operated on same frequency band. CoMP-Joint Transmission is used to send data to different UEs.

In Fig. 19, the green area has good range of RSRP and RSRQ values but in brownish area RSRP dropped from threshold level (i.e., a value of RSRP is set by network operator and ranges are given in Table.1) whilst RSRQ depends on conditions such as load, interference etc. More explanations for the proposed scheme can be seen in Fig. 19.

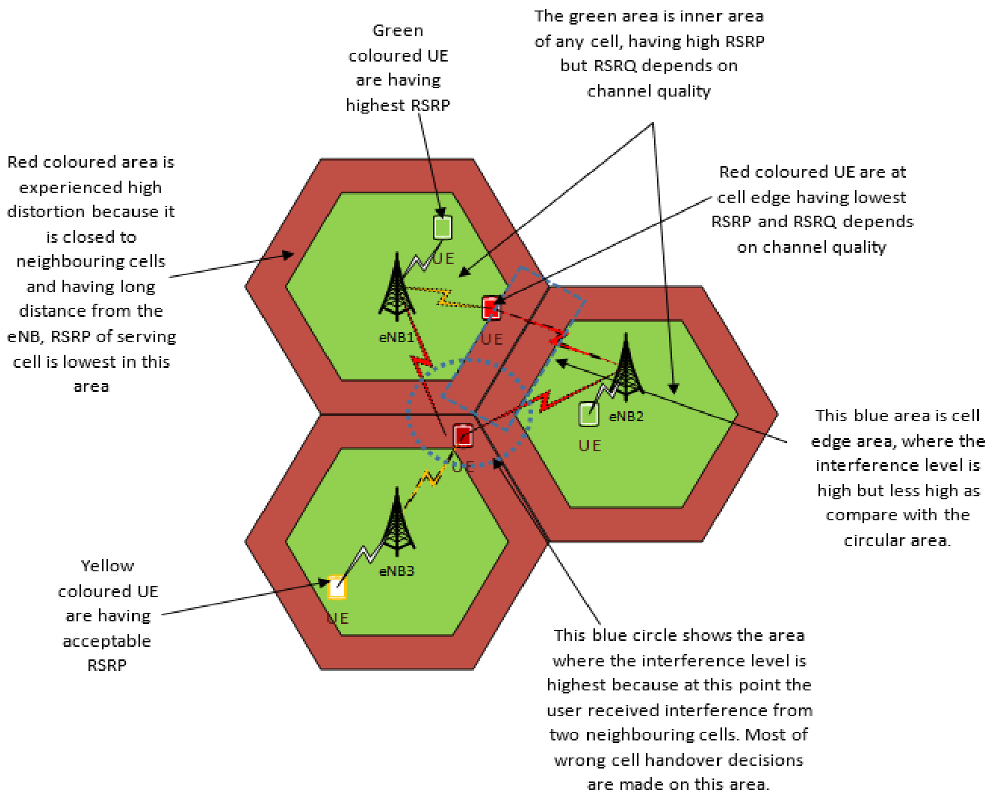

Fig. 19 An overview of Proposed Scheme

The important calculations to facilitate the making of decision to reduce the number of unnecessary handovers can be seen below.

Received Signal Received Power: RSRP is defined as the linear average received power by the UE (or any receiver) from the reference signal resources elements over desired bandwidth (i.e., 5MHz, 10MHz and 20MHz). The general formula derived from above definition for RSRP is [56] [89] [90];

$$RSRP = \frac{1}{K}\sum_{k=1}^{K} P_{rs,k} - - - (1)$$

Where $P_{rs,k}$ is the estimated power (in Watts) of kth Reference Signal (RS) Resource Element (RE) in Physical Resource Block (PRB). Moreover, PRB is a smallest transmission unit of downlink LTE-A. It consist of 12 subcarriers and 7 OFDM as shown in Fig. 20. In PRB, There are four RS presents, having fixed position in time domain and that is first and forth OFDM symbols. Following Fig. 20 shows that details description of PRB [11] [91].

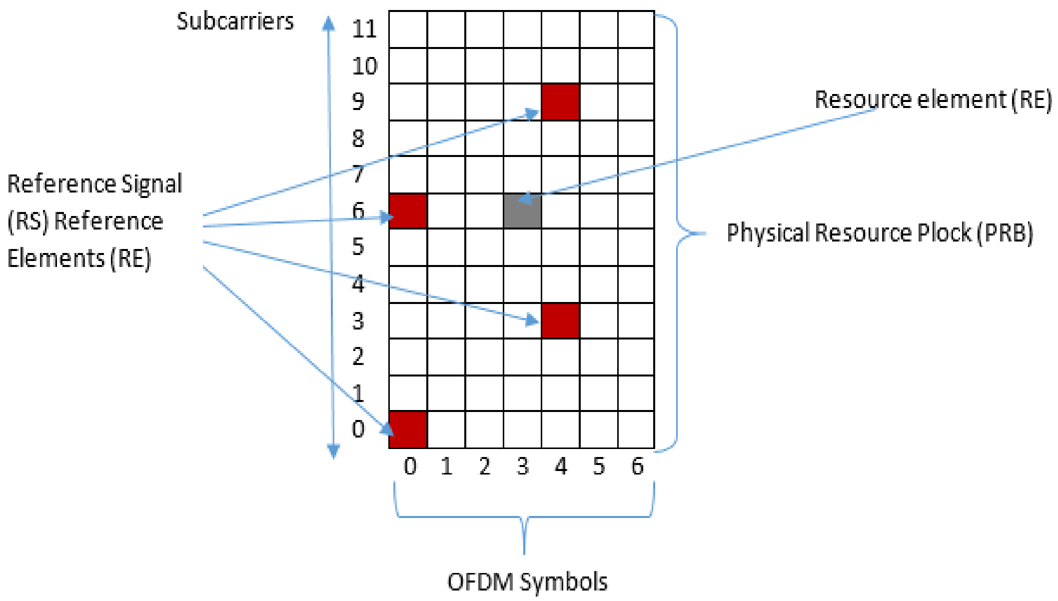

Fig. 20 Overview of Physical Resource Block (PRB) (c.f., [11] [91])

So for calculations of RSRP these reference signals are important because the UE is measured RSRP value in these RS and feedback to the serving cell. These RS only measure the power excludes the noise and interference. The measured value of RSRP for UE to eNB is determined with help of following formula;

$$RSRP_{ue->eNB_i} = P_{tx->eNB_i} + G_{eNB_i} - PiL_{ue,\ eNB_i} - \varepsilon_{ue,\ eNB_i} - - - (2)$$

Where $P_{tx->eNB_i}$ is transmitting power ith eNB (normally a serving eNB) and G_{eNB_i} is antenna gain of serving eNB, $PiL_{ue,\ eNB_i}$ is path loss between UE and serving eNB, $\varepsilon_{ue,\ eNB_i}$ the shadowing fading with log-normal distribution with zero mean and 3dB standard deviation [92].

In equation '2' the path loss calculations are based on following formulas.

Path Loss Calculations*:* for path loss calculation in formula (2) can find with help of following formula [85] [93].

$$PiL = 46.3 + 33.9\log(f) - 13.82\log(G_{eNB}) - a(G_{UE}) + (44.9 - 6.55\log(G_{eNB}))\log(d_i) - -(3)$$

Where

$$a(G_{UE}) = (1.11log(f) - 0.7)G_{UE} - (1.56log(f)) - 0.8)$$

$$d_i\ =\ UE\ distance\ from\ eNB\ in\ km$$

$$G_{eNB} = eNB(transmitter)\ antenna\ gain$$

$$G_{UE} = UE(Receiver)\ antenna\ gain$$

Fig. 21 gives the overview of calculations in details. Where UE is located at the cell edge of hexagonal macro cell having Radius 'R' and having direction 'θ' between $(0, 2\pi)$. UE had 'd_i' is distance from eNB. Transmission and Receiver antenna Gains are 'G_{eNB}' and 'G_{UE}' respectively.

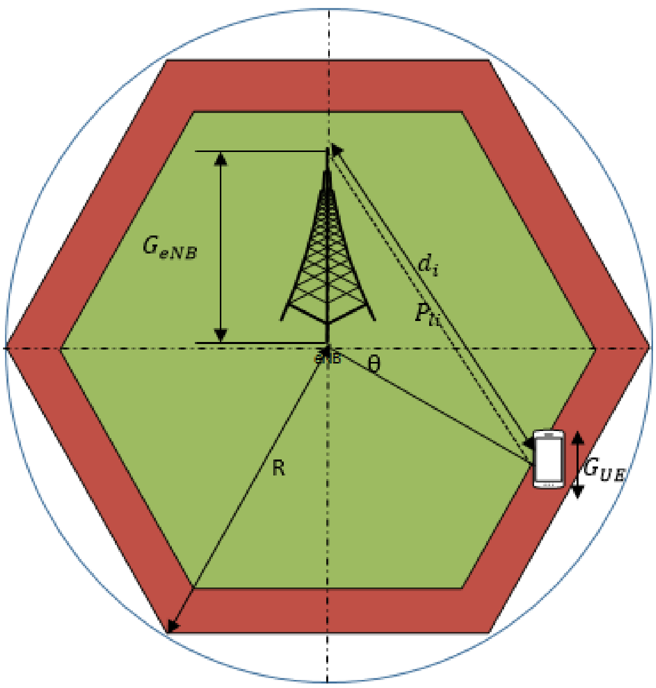

Fig. 21 Calculation of RSRP/Path loss

Calculations of RSRQ: RSRQ indicates the quality of received signal and it can be measured with help of following formula;

$$RSRQ = N_{RB}\left(\frac{RSRP}{RSSI}\right) - - - - - - (4)$$

Where 'N_{RB}' total number of resource blocks over which a measurement is conducted. Where RSSI "comprises of the linear average of the total received power observed only in OFDM symbols contain the cell specific reference symbols for antenna port over 'N_{RB}' resource blocks in the measurement bandwidth by UE from all sources including adjacent channel interference and thermal noise and co-channel serving and non-serving eNB," [89].

5.3. An Algorithm for Proposed Handover Scheme

The main aim of proposed handover scheme is to reduce the number of unnecessary handovers and improve performance of users at cell edges. For this purpose proposed handover scheme is divided into two mode; CoMP mode and handover mode. In CoMP mode, UE receives RSRP from the serving eNB below than threshold level (a value set by network operator) but the level of RSRQ is not bad or dropped from certain level. In such situation, conventional and existing handover schemes, they triggered handover mode, but in proposed scheme CoMP mode is triggered instead of handover initialisation decisions. By triggering CoMP mode, the UE start receiving data from multiple eNBs on basis of CoMP types such as Joint transmission (i.e., UE received data from all nodes in coordinated way) or Beam forming (i.e., the eNBs are coordinated to each other, but UE receive data only from single eNB).

On the other hand, when UE receives RSRP below than threshold level from the eNB and RSRQ level is also bad, then handover mode is triggered and handover process will initiate. Mathematically and logically the triggering of CoMP and handover mode are explained below:

For Triggering CoMP Mode: when following condition become true the CoMP mode will activated.

$$Condition\ 1: \qquad RSRP_{serving\_cell} + RSRP_{Boost} < RSRP_{CoMP\_Th}$$

Where '$RSRP_{serving\_cell}$' measured in 'dBm' is power received by UE from the serving eNB and '$RSRP_{Boost}$' is value set by network provider and it is using to increased bit level of RSRP and RSRQ to take time to decide the handover decision. Similarly '$RSRP_{CoMP\_Th}$' measured in 'dBm' is threshold level of RSRP at which CoMP mode is triggering and this value is also decided by network operator. RSRP measured value is range between -44dBm to -140dBm. Following table shows in details RSRP values in different ranges [46] .

Measured RSRP	**Signal Strength**
-44dBm to-80dBm	Excellent
-81dBm to-90dBm	Good
-91dBm to-110dBm	Mid Cell
-111dBm to More	Cell edge

Table. 2 Different range of RSRP Values (c.f., [18] [19])

For Triggering Handover Process: When condition 1 and condition 2 are true then handover process will initiated.

$$Condition\ 2:\ \ RSRP_{CoMP\_Th} + RSRP_{offset} < RSRP_{Neigh\_Cell}$$

$$Condtion\ 3: RSRQ_{Min} < RSRQ_{serving\_cell} < RSRQ_{Max}$$

In condition 1, '$RSRP_{CoMP\_Th}$' is same as condition 1, '$RSRP_{offset}$' is received power offset value that ranges from $\pm 2\ to\ \pm 3$ in our case because all eNBs having same transmitting power. Actually When CoMP mode is activated then UE is connected with more than one eNB, so it receive different received power from eNBs in case of diversity scheme. Therefore this offset value is used to make sure the reported or measured RSRP value is not less than the individual value of RSRP[56] [89] . The selection of value is deepening on the interference level and noise level. Similarly '$RSRP_{Neigh\_Cell}$' is received power by UE from neighbouring cells.

In condition 2, '$RSRQ_{serving\_cell}$' is channel quality indicator measured by UE in serving eNB and '$RSRQ_{Min}$' and '$RSRQ_{Max}$' are minimum and maximum range of RSRQ set by network operator to decide the channel quality is bad or good. Following table shows most common ideas of RSRQ values [89].

Measured RSRQ	**Channel Quality**
-3dBm to-9dBm	Excellent
-10dBm to-12dBm	Good
-13dBm to-14dBm	Acceptable
-15dBm to More	Cell edge, Bad

Table. 3 Different Range of RSRQ values (c.f., [13] [19])

5.3.1. Flow Chart

Following Fig. 22 shows in details, how proposed handover scheme works to reduce the unnecessary handover decisions.

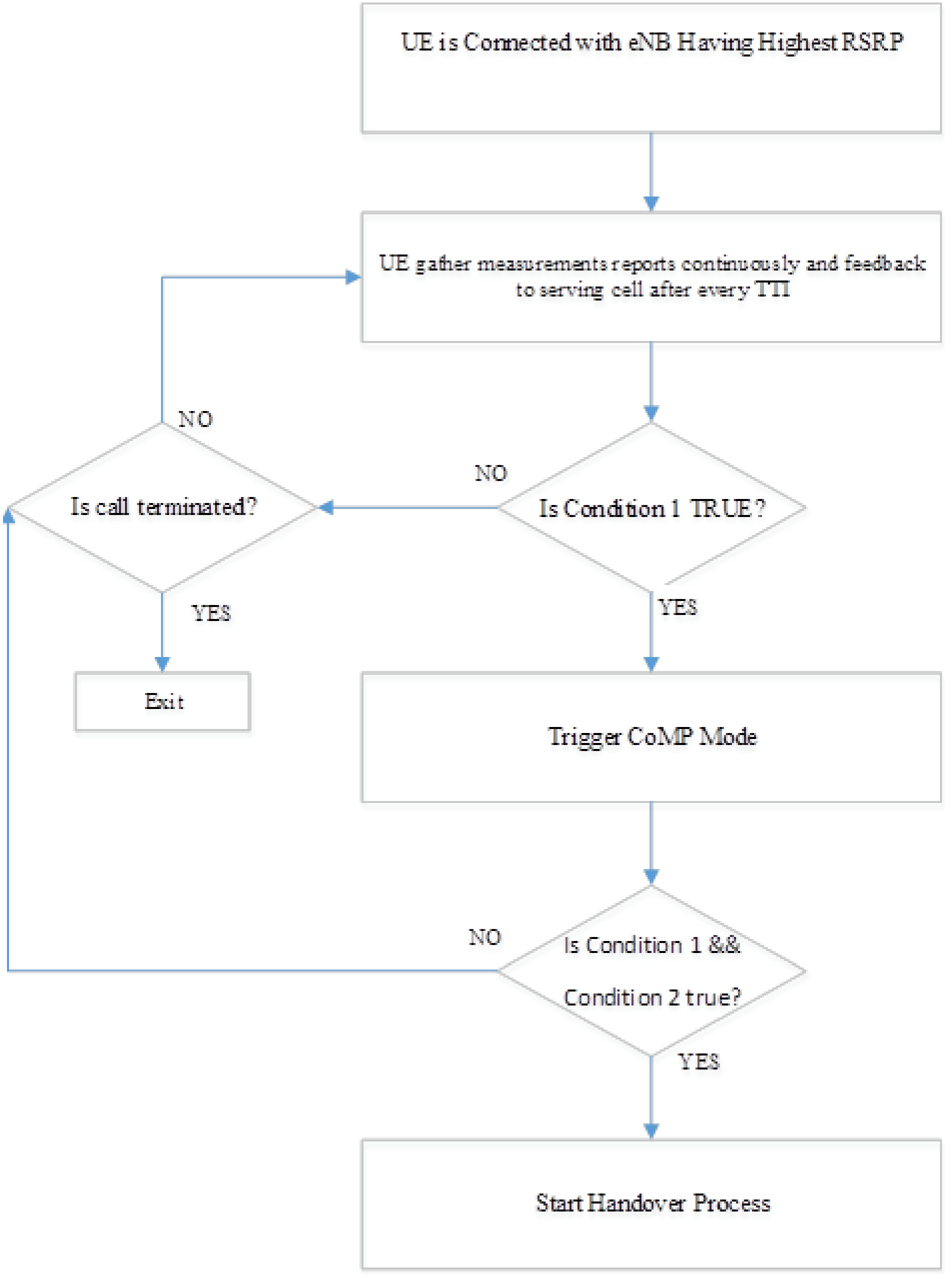

Fig. 22 Flow chart of Proposed Handover Scheme

5.4. Performance Measures for Unnecessary Handovers

The following performance measures for determining the number of unnecessary handovers are presented below.

1. RSRQ and RSRP measurements: In proposed handover scheme the value of RSRP and RSRQ plays key role in decision of handover by triggering CoMP mode or handover mode. Thus, the behaviour of these values are analysed against different bandwidth value, load value and by considering external noise.

2. Total Number of Handover Decisions in Conventional Handover Schemes (THCS): Conventionally, the handover process is started, when UE experienced low RSRP than threshold level. In proposed algorithms at same RSRP's threshold level the CoMP mode is triggered. Therefore, following formulas is used to calculate the number of handover in conventional handover schemes

$$THCS_{1\rightarrow N} = Sum\ (Countif\ \{1\!:N, \text{"Condtion1"}\})$$

Where 'THCS' is total number of handover decision for 'N' number of users present in the network. The number of handovers are counted, whenever condition 1 is true during the simulation.

3. Total Number of Handover Decisions in Proposed handover Scheme (THP):

In proposed algorithms the total number of handover decisions are calculated when conditions 2 and 3 are true.

$$THPS_{1\to N} = Sum\ (Countif\ \{1{:}\,N, \text{"Condition2" "Condition3"}\})$$

Where 'THCS' is total number of handover decision for 'N' number of users present in the network. Whenever condition 2 and condition 3 are true, it counts and return the sum of numbers.

4. Percentage of Unnecessary Number of Handover (UNH): Percentage of unnecessary number of handovers can be calculated with help of following formula;

$$UNH\ (\%) = \left(\frac{THCS_{1\to N}\ -\ THPS_{1\to N}}{Total\ Number\ of\ Handover}\right) \times 100$$

Where total number of handover in conventional system are always higher as compare with the total number of handovers in proposed system. Therefore the difference of THCS and THPS gives UNH in our algorithm.

For measuring performance of proposed scheme following discrete time simulation environment is considered.

5.4.1. The Simulation Environment

The performance of proposed handover scheme is evaluated on numerical results of RSRP and RSRQ, the calculations are based on LTE-A downlink system level simulator [55] [21]. For implementation of proposed handover scheme a single cell is considered that has hexagonal shape. UE are uniformly distributed over the cell with in the coverage area of eNB. Moreover, the position of eNB is at the centre of cell, and having 3km radius. In addition, there are considered bandwidth of 5MHz, 10MHz and 20MHz with 25RB, 50RB and 100RB respectively. There is also considered 0.5ms duration required for transmitting 7 OFDM with 2GHz carrier frequency. Each RB is receiving equal transmission power of 20mwatt from serving eNB. In addition, the assumptions and parameter's value used in numerical calculations of RSRP and RSRQ for reducing unnecessary handover are listed below.

Assumptions

- Assume eNB is located at the centre of cell.
- UE's are uniformly distributed over the cell.
- All UE's are located in the cell coverage area. It means no UE is located outside the defined radius of cell.
- UE position in the cell is randomly choose from $(0, 2\pi)$ and constant all the time.
- The speed of UE is constant inside the cell. Initially they are stationary.
- Each reference signal contain equal power without any interference and disturbance.

Input Data for Simulation Parameters

Simulation Parameters	**Values**
Cell Radius	3km
Bandwidth/Resource Block	5 MHz/25RB, 10MHz/50RB, 20MHz/100RB
Number of subcarrier per RB	12
Number of OFDM symbols	7
Subcarrier spacing frequency	15kHz
Slot duration	0.5ms
Carrier frequency	1800MHz
eNB Transmission Power	20Watt
eNB Antenna Gain	30dBm to 50dBm
UE antenna Gain	1dbm to 10dBm
Sub-carrier frequency	15KHz
Path loss model	Cost 231 Hata model
Shadow fading	Log normal distribution with zero mean and 3dB standard deviation
RSSI	-75dBm to -90 dBm
$RSRP_{boost}$	3dBm
Time Transmission Interval (TTI)	1ms
No of UE	30 , 50 , 100

Table 4: Input Data for Simulation Parameters (c.f., [65] [77])

5.5. Numerical Experiments and Interpretation

This section presents numerical results of the proposed handover scheme and carries out comparisons with conventional handover schemes.

1. The impact of RSRP value at different bandwidth against Distance

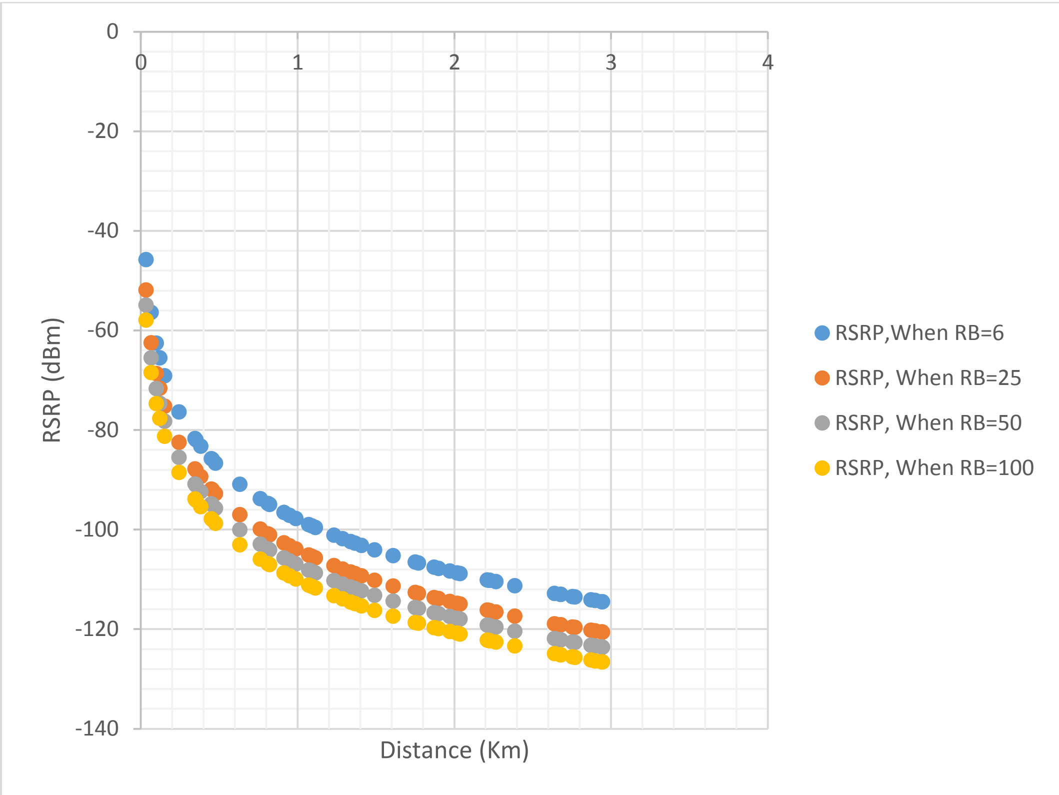

Fig. 23 RSRP at Different Bandwidth against Distance

Fig. 23 illustrates the relationship between RSRP and distance at different values of resource blocks. As UE's distance is increased from the eNB, the RSRP value is dropping, as seen in above results, when UE has minimum distance from eNB, the

RSRP value is at maximum level -39.9dBM ($\approx -40dBm$) against all cases of RB. On other hand, when distance is maximum about 3km the RSRP dropped maximum to -120dBm (approximately). This is happened because as UE's distance increased from eNB, it experienced less power and high distortion that's why the received power is reduced at the cell edge. The main reason of decreasing RSRP is large fading (i.e., factor such as multipath, speed of surrounding objects, transmission bandwidth etc.) affecting receiving power [94].

On the other hand, in Fig. 24, the RSRP's curves for different number of resource block have minor variations. When RB value is increased the value of RSRP is decreased. That is happened because of interference among resource elements. When we increased number of RBs, the number of resource elements are increased, therefore the interference among resource elements are increased. As a result, the value of RSRP is decreased for high number of RB [56] [95].

2. *The impact of RSRQ against load at RSRP, RSRP boost and with External Interference (EI)*

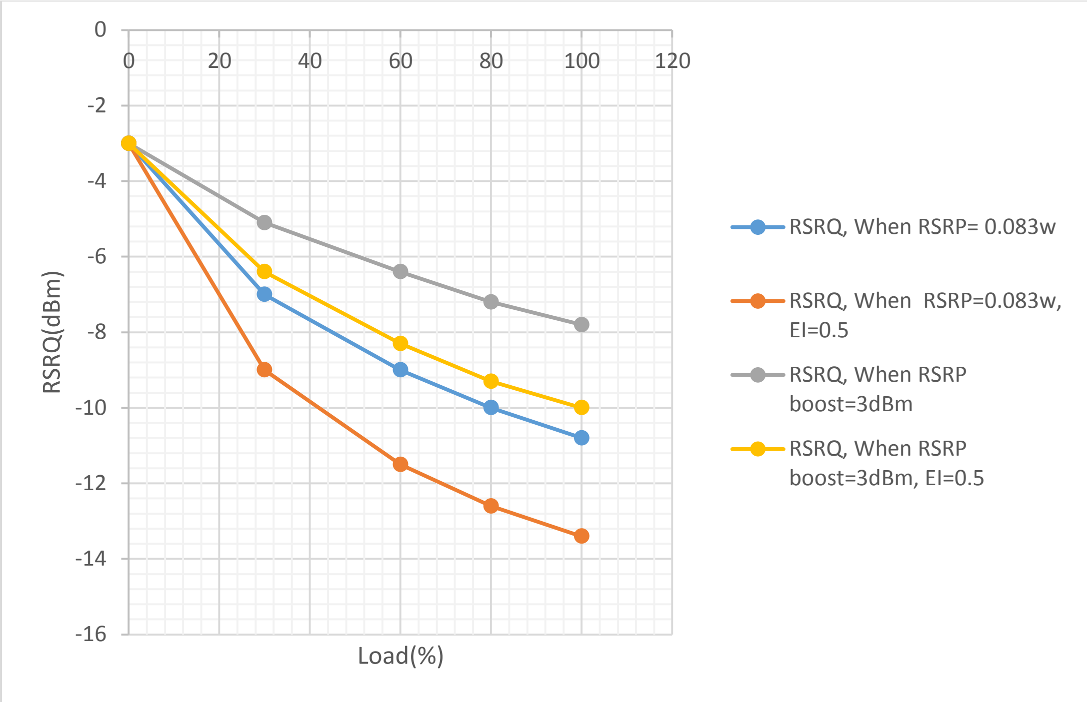

Fig. 24 The Impact of RSRQ against Load

Fig. 24. Demonstrates behaviour of RSRQ against load with and without of $RSRP_{boost}$ and External Interference (EI). The EI considered here, because quality of channel is highly effected with this factor and effecting the handover decisions. Initially, when load is '0%', the RSRQ value is maximum at -3dBm in all considered cases. The reason is, in absence of load (i.e., all resource blocks are free), the interference is almost negligible in among resource elements, and the value of RSSI and RSRP is almost same, that's why the channel quality is best. But when we increased load to 100%, the value of RSRQ is dropped to maximum level in all

considered cases. The reason is the load increased, and RSSI value is also increased and interference level among resource elements become high, that's why the quality of channel is dropped. The best value of RSRQ is observed when there is no external interference and RSRP value is boost, in such case the best value is -3dBm and minimum value is -7.8dBm. So in such case there is no need of any handover until the situation become worst even the RSRP value is at his lowest.

3. Number of Handover Initialisation Decisions (NHID)

Fig. 25 Shows the Number of Handover Initialisation Decisions (NHID) for conventional and proposed algorithms. The NHID are increased when the users are increased in all considered cases. The reason is, when users are increased it means the load is increased and the value of RSRP and RSRQ are decreased and become lower than their threshold level that's why the NHID increased. But by comparing the conventional algorithms, the proposed handover has less number of NHID because proposed algorithms is checking the RSRP value along with RSRQ value. We observed that in case of 5 MHz Bandwidth, when number of UE are 30 the NHID are 46.6% and 16.6% of total users for conventional and proposed algorithms respectively. Similarly, in case of 20 MHz Bandwidth for same number of users the

NHID are 80% and 36.6% of total users for conventional and proposed algorithms respectively.

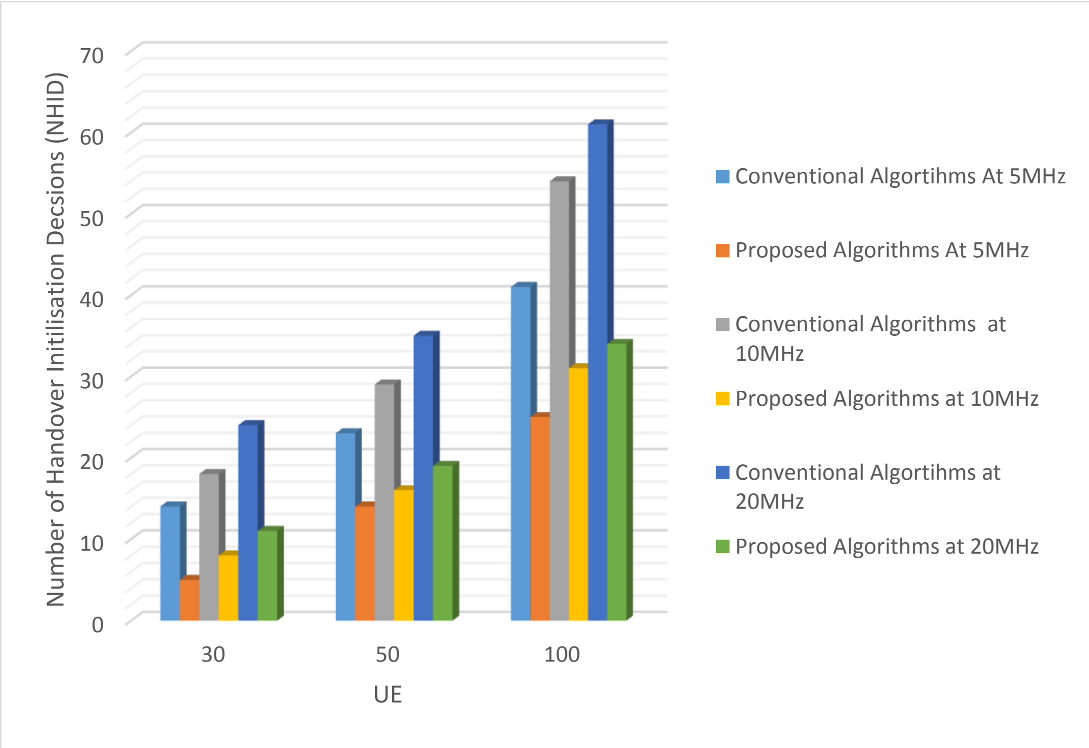

Fig. 25 Number of handover Initialisation Decisions between conventional and proposed handover scheme

As a result, the number of handover initialisation decision are decreased in proposed scheme as compare with conventional handover schemes but if compare the results between different bandwidth, the NHID is bit increased in proposed scheme, this is due to the findings present in Fig. 24

4. Percentage of Unnecessary Number of Handovers

Fig. 26. Illustrates the percentage of unnecessary handover against no of UE. When number of UE are 30, the conventional handover schemes as compare with proposed handover scheme have 47%, 37.14% and 38.4% (for 5 MHz, 10 MHz, and 20MHz respectively) more unnecessary handover decisions. Similarly, when number of UE are 100, the conventional handover schemes have 24.2%, 28.2% and 28.4% unnecessary handovers as compare with proposed handover scheme. It means with help of proposed handover scheme, the above mentioned unnecessary handover can reduced. Moreover, that reduction in handover decision lead to system performance.

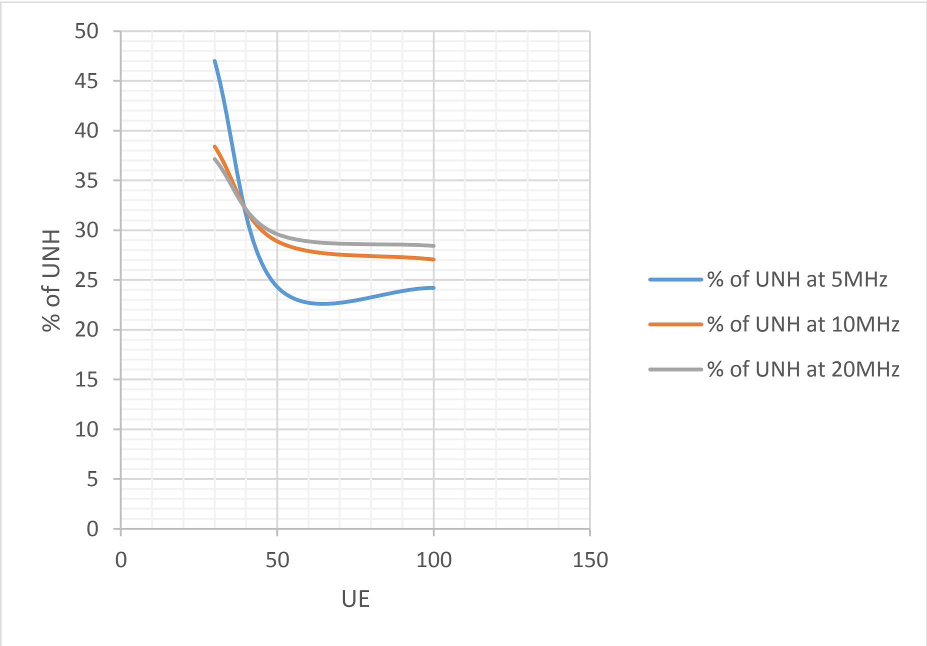

Fig. 26 Percentage of Unnecessary Number of Handovers

Summary of Chapter 5

An efficient handover scheme is proposed in this chapter to reduce number of unnecessary handovers in wireless networks based on CoMP and the value of RSRP and RSRQ of UE. For this purpose, CoMP and Handover modes are introduced in this chapter. Also two different threshold level of RSRP value were introduced for both modes. At first level of threshold, CoMP mode is triggered (i.e., at same threshold level, conventional handovers are triggered). Thus, following CoMP mode, the handover mode is activated to further check the RSRP signal power along with RSRQ signal quality to make sure acceptable conditions of network prior to taking final handover decision. At the end, the experimental results are presented and discuss between proposed and conventional handover schemes. These results shows the proposed handover scheme is more effective and reliable than conventional handover schemes.

Chapter 6: Optimised Feedback and Resource Sharing Process During CoMP-JT Based Handover in LTE-A System for Cell Edge Users

6. Introduction

As discussed above Coordinated Multipoint (CoMP) technique is providing solutions of ICI at the cell edge. Moreover, CoMP used different categories such as Joint Transmission (JT) and Coordination Beamforming (CB) to overcome problems at the cell edge region. The details of these categories are given in chapter 3. Furthermore, JT is adopted in present handover scheme to reduce ICI level by converting it to enhancement signal. The reason of enhancement is, in presence of CoMP-JT at the cell edge, UE receives data from multiple eNBs. Although CoMP-JT technique is reducing ICI level at the cell edge but its feedback and resource sharing process is very complicated and difficult because in CoMP-JT after fixed time interval (i.e., called Transmission Time Interval, normally its value is 1ms) UE sends feedback to serving eNB that effect its performance in presence of backhaul network (i.e., network comprises the intermediate links between the core network). On other hand, when CoMP-JT is triggered the consumption of radio resources is high because UE receives radio resources from multiple eNBs. So there is need of optimised method that decide the right time and right location of CoMP JT activation. For example, at centre of cell the Inter-Cell Interference (ICI) level is very low so there is no need of triggering CoMP-JT. In this context, a CoMP-JT based handover scheme is proposed to find solution of excessive feedbacks and inter coordination of eNBs to decide radio resources among different UEs.

6.1.Existing and Related Work

In [65] author suggested limited CoMP handover algorithm based on utilization of resource block. During selection and reselection of eNB, it ignored the eNB that is highly saturated and accepted one having low utilization of resource block. Also author described efficient way of resource sharing on basis of channel quality with help of RSRP. In [82] author presented CoMP handover algorithm by introducing capacity integrated factor, that capacity indicator is combination of present and historical utilization of resource block. So the selection or eNB is based on this factor. Moreover, the results of [65] [82] shows the improvements in RB utilization and throughput by comparing simple CoMP handover algorithms. In [86] author presented capacity based algorithm and it has more a less same scheme and concept as presented in [65] [82]. In all above algorithms, CoMP mechanises is applied in good and efficient way but they did not address how to overcome the drawbacks of CoMP in details such as excessive feedback and coordination of UE at the cell edge. In addition, in all above algorithms the handover decision mechanism is common. It is divided in three parts Time to Trigger duration, HOM and value of RSRP (when serving cell experience low RSRP than target cell, handover is triggered). These steps are similar as traditional handover schemes. Moreover, the assessment criteria is bit different in these algorithms but more a less revolve around the resource blocks and history information table that maintain by UE. The important detail of radio resources is missing in these algorithms expect [65], who maintain radio resources during his algorithm scheme.

6.2.Proposed CoMP-JT based Handover Scheme

In proposed CoMP-JT based handover scheme to overcome the problems related with excessive feedback and resource sharing consider following amendments in already implemented handover schemes.

UE Categories: UEs are categorised into the cell edge users and cell centre users on basis of signal measurements such as RSRP and RSRQ. Furthermore, cell centred users experience good signal measurement because the ICI level is low at centre of cell. On the other hand UEs are located at the cell edge region are cell edge users because at the cell edge the signal measurements are not good due to high level of interference caused by neighbouring eNBs. In this context, UEs present at centre are categorised as Non-CoMP UE and UEs present at the cell edge region are categorised as CoMP UE. In proposed scheme, with help of signal measurements discouraged to triggered CoMP-JT for Non-CoMP UE, that's lead to reduce the feedback complications and save radio resource consumptions.

eNBs Coordination Scheme: In CoMP-JT based handover, an optimised coordination scheme is required to decide radio resources among the CoMP UE and Non-CoMP UE. Therefore, the coordination scheme discussed in [96] is used in proposed system. In which the CoMP UE are considered as multi-site users because they are connected with multiple eNBs at a time and Non-COMP UE are considered as single-site users because they are connected with single eNB at a time. The resources sharing among these users are explained with help of following example, in which two eNBs are jointly served to cell edge users (CoMP UEs). Each eNB has six resource blocks (1.4 MHz BW) for one scheduling interval and at a time only one RB is assigned to UE (selected UE). There are three UEs (UE1, UE2 and UE3) are attached with eNB1 and three UEs (UE4, UE5 and UE6) are attached with eNB2. Fig. 29 shows when CoMP mode is not triggered then two resource blocks are assigned to each UE in both eNBs on basis of scheduling criteria. On other side, in case of Fig. 28 when CoMP UE are considered then two RBs are assigned to UE3 and one RB is assigned to UE4 by eNB1 and eNB2. So total six RBs are assigned to cell edge users and six RBs are assigned to cell centre users. But only one RB is assigned to UE5 and UE1 because they are receiving high RSRP at cell centre. This method may increase the system throughput at the cell edge but the overall system throughput is degraded because of unbalanced resource sharing among centre users and cell edge users.

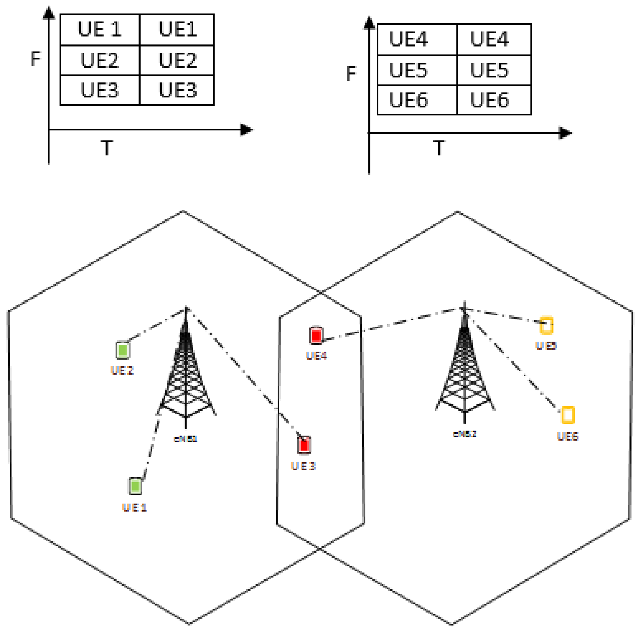

Fig. 27 Assignment of RB in single-site approach (c.f., [96])

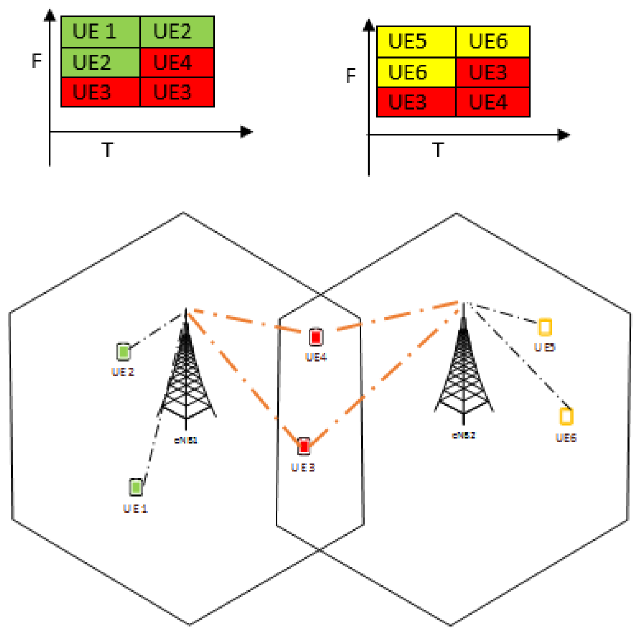

Fig. 28 Assignment of RBs in multi-site approach (c.f., [96])

Therefore, for current CoMP JT handover, following resource sharing scheme is adopted.

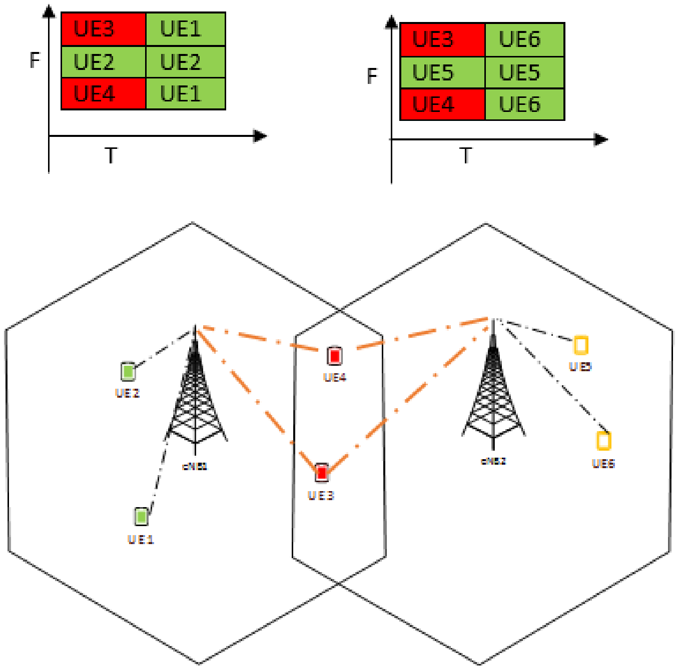

Fig. 29 RBs assignment in proposed CoMP JT handover Scheme (c.f., [96])

In above example UEs present at cell centre (UE2, UE3, UE5 and UE6) are assigned two RBs. And the cell edge UE assigned one RB from respective eNBs, so total two RBs assigned to users at the cell edge. So in this scheme the resource allocation is based on fairness and fairly divided among users at cell centre and cell edge to increase the overall system throughput.

***Selection of eNBs* :** In CoMP JT, for Cooperative Transmission Set (CTS) (i.e., one of element of CoMP technique) the number of eNBs are set by network provider. UE selects eNBs on signal measurements and always select eNB having highest RSRP and RSRQ and having capacity to accommodate more UEs. To avoid the excessive feedback reports, always prefer to choose minimum number of eNBs as requirements. As mentioned above, if large number of eNBs are participating in CoMP mode, the overall system throughput may degraded [96] because of fixed reporting time.

6.2.1. CoMP-JT Sets Used in Proposed Handover Scheme

For implementing proposed handover scheme following CoMP-JT sets are considered:

- Serving cell: User equipment (UE) has only one serving cell.
- Measurement set: it is configured by evolved node B (eNB) for UE after receiving feedback from UE.
- COMP coordinate set (CCS): CCS is subset of measurement set that directly or indirectly responsible of communication

- COMP transmission set (CTP): CTP is subset of CCS and it directly send information or data to UE

There are also some control elements used in this scheme such as; Measurement Period, Time To Trigger (TTT), Handover Margin (HOM) and RSRP Boost value. Where measurement period is a time period that is defined by network operator and used to check the condition of handover. HOM is a constant value that is used to avoid unnecessary handovers and also decide the right cell selection at right time. This is a threshold value of RSRP between serving and target eNB. In LTE-A the value the HOM value should be more than '1' because when the difference of RSRP between serving and target is more than '1', then UE reports to serving cell. RSRP boost value is optional here, it is used to boost RSRP value at some instance at cell edge to avoid CoMP mode or handover mode to trigger. This value is best used in proposed scheme because we can delay maximum the triggering time of CoMP mode to save the radio resources.

6.2.2. An Algorithm for Proposed Handover Scheme

To measure the handover scheme and CoMP JT mode in proposed handover scheme, the combination of RSRP and RSRQ are introduced. These two values are UE directly reported to serving cell to decide the handover measurements and also these two value are helpful to categorised the CoMP UE and Non CoMP UE. The proposed network scenario is shown in Fig 30. Where an eNB is surrounding by six homogeneous eNBs and CoMP UE and Non CoMP UE randomly scattered in eNB's coverage area.

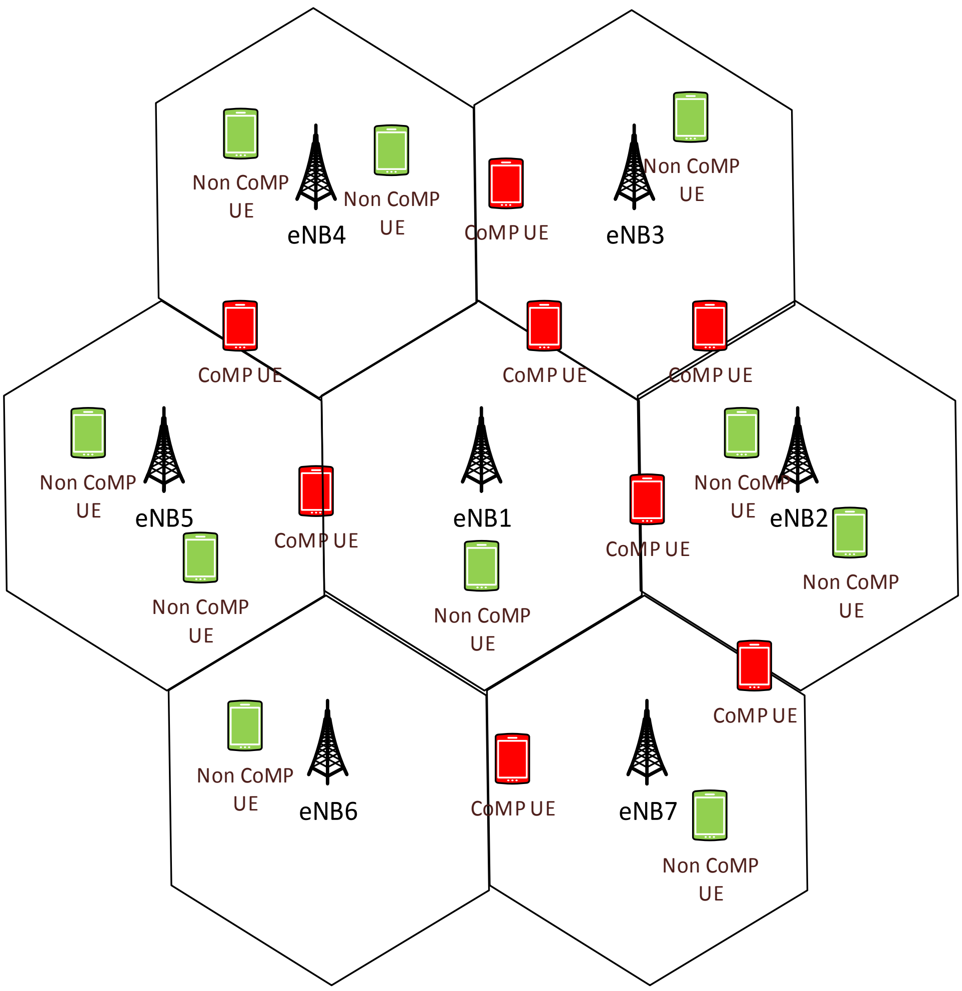

Fig. 30 The Proposed Network Scenario

Following are main steps of proposed algorithms;

Step 1: Always UE is attached with serving eNB having highest RSRP and having in good range of RSRQ (normally between -3dBm to -10dBm)

Step 2: If the measurement period is valid check further the category of UE, is CoMP UE and Non CoMP UE with help of following condition.

$$RSRP_s + RSRP_{boost} < RSRP_N - - - - - (1)$$

Where '$RSRP_s$' is RSRP value of serving cell and '$RSRP_{boost}$' is RSRP value, that is used to boost the signal and '$RSRP_N$' is RSRP value that is any of neighbouring eNB's value that is higher than serving eNB calculated by designated UE. So if the statement is true then the UE is CoMP UE because it is located on cell edge, where it is experienced interference from neighbouring cell and follow the step 3, otherwise no need of CoMP mode and procedure is followed as normal until condition '1' is true.

Step 3: Again check, is measurement period valid. If yes then check the measurement set recursively that is reported by UE to serving cell for obtaining CCS and CTP. For CCS select top four eNBs having highest RSRP by comparing with each other all values present in measurement set. Similarly, for CTP select three eNBs from CCS, they have highest RSRP values by comparing all values present in CCS. If the measurement period is expired go to step 2.

Step 4: If the measurement period is valid, the eNB present in CTP are started sending data to UE. And this process is continue until the UE exist from the system or following become following conditions true for handover.

$$RSRP_{Target\_CTP} - HOM > RSRP_s --- (2)$$

$$RSRQ_{Min} < RSRQ_s < RSRQ_{Max} --- (3)$$

$$RBused_{Target\_CTP} < RBmax_{Target\_CTP} --- (4)$$

Where '$RSRP_{Target\_CTP}$' is RSRP value of eNB present in CTP set because in CTP we have already eNBs having top RSRP after serving cells. Similarly '$RSRQ_s$' is RSRQ is channel quality conditions that UE is received by serving eNB. The value minimum and maximum range of RSRQ depends on the scenario. This factor is basically used to discourage to activate the handover mode in presence of good channel quality. '$RBused_{Target\_CTP}$' is used number of resource block of targeting eNB in CTP and '$RBmax_{Target\_CTP}$' is maximum number of resource blocks present in targeting eNB in CTP. This condition is basically used the capacity of target eNB to accommodate more users.

6.3. Performance Measures of Proposed Handover

Utilization of Resource Block: For considering cell selection and reselection, the value of RB utilization is very important. If the RB utilization is very high, it means the cell is saturated and not having capability of accommodating more UEs even it has high value of RSRP. On the other hand if the RB utilization value is low, it means cell is capable to accommodate more UEs. Following formula is used to calculate the utilizations of resource blocks [21].

$$RB_{Utilization} = \sum_{t=1}^{T}\sum_{c=1}^{K}\left(\frac{RB_{used(c)}}{RB_{Max(c)}}\right)(t)$$

Where $RB_{used(c)}$ and $RB_{Max(c)}$ is used and maximum resource block of cell c (eNB) at time 't'. K is presents total number of eNBs and 'T' is total simulation time.

System Throughput: System throughput is defined as the total number of resource elements received by all users without error in specific time period. Mathematically it is defined as[21] ;

$$Systme\ throuput = \sum_{t=1}^{T}\sum_{i=1}^{U}(REtransmit)_i(t)$$

Where ‘T’ and ‘U’ are denoted as total simulation time and total number of users respectively and $(REtransmit)_i(t)$ is total resource elements to users ‘i’ at time ‘t’.

6.3.1. Simulation Environment

To measure performance of proposed handover scheme, a LTE-A Downlink System level Simulator [21] is used. Consider network having 7 hexagonal cells as shown in Fig. 31. The performance of proposed handover scheme is evaluated on LTE-A downlink system level simulator [55] [21]. For implementation of proposed handover scheme a seven cells are considered that has hexagonal shape. UE are uniformly distributed over the cells with in the coverage area of eNBs. Moreover, the position of eNB is at the centre of cell for all seven eNBs, and each one having 100m radius.

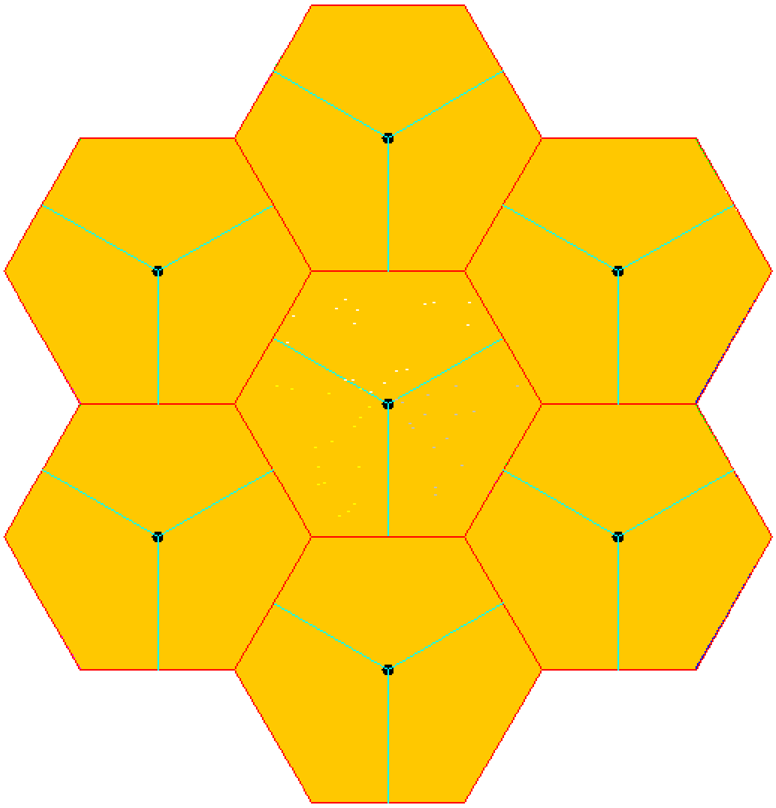

Fig. 31 Simulation Environment for CoMP-JT based Handover Algorithm

In addition, there are considered bandwidth of 5MHz with 25RBs. There is also considered 0.5ms duration required for transmitting 7 OFDM with 2GHz carrier frequency. Each RB is receiving equal transmission power of 20mwatt from serving eNBs. In addition, the assumptions and parameter's value used in in proposed scheme are listed below [77].

Assumptions

- Network architecture is consist on seven hexagonal macro cells.
- UE's location are uniformly distrusted
- Every UE is connected with its own serving cell
- UE are categorised into cell edge and cell centre users
- Network has two mode of transmission, COMP and Non-COMP
- Cell edge user are in COMP mode and cell centre users are in Non-COMP mode
- For resource sharing Proportional Fair based scheduling is used

Input date Parameter's value

Simulation Parameters	**Value**
Cell Radius	100m
Bandwidth/Resource Block	5MHz/25RB
Number of subcarrier per RB	12
Number of OFDM symbols	7
Subcarrier spacing frequency	15kHz
Slot duration	0.5ms
Carrier frequency	2000MHz
eNB Transmission Power	20Watt
eNB Antenna Gain	30dBm to 50dBm
UE antenna Gain	1dbm to 10dBm
Modulation and coding scheme	16QAM and 64QAM
Sub-carrier frequency	15KHz
Path loss model	Cost 231 Hata model
Shadow fading	Log Normal Distribution with zero mean and 3dB standard deviation
RSSI	-75dBm to -90dBm
$RSRP_{boost}$	3dBm
Measurement Period	10ms
Time Transmission Interval (TTI)	1ms
No of UE	30 , 50 , 100

Table 5 Input Data for Simulation Parameters (c.f., [81] [76])

6.4. Results and Interpretation

This section presents numerical results of the proposed handover scheme and carries out comparisons with existing CoMP-JT based handover schemes.

1. Comparison of Utilization of Resource Block between proposed and existing handover schemes.

Fig. 32 shows the utilization of resource block between proposed and existing handover schemes. In both algorithms the percentage of utilization is increased when UEs are increased. This happened because when more users are coming in the system, more resource blocks are used to transmit data in downlink. That's why in both cases the network become saturated when number of UEs are increased. When number of UE are 30, the proposed handover scheme has 48.12% utilization of RBs as compare with 70.53% of existing handover schemes. Similarly, for 50 number of UEs 75.23% and 85.6 % for proposed and existing handover schemes respectively. Moreover, if the number of UEs are increased in the system, it become saturated and 100 percent the resource blocks are utilized. No more uses are accommodate at cell edge area and cell centre area.

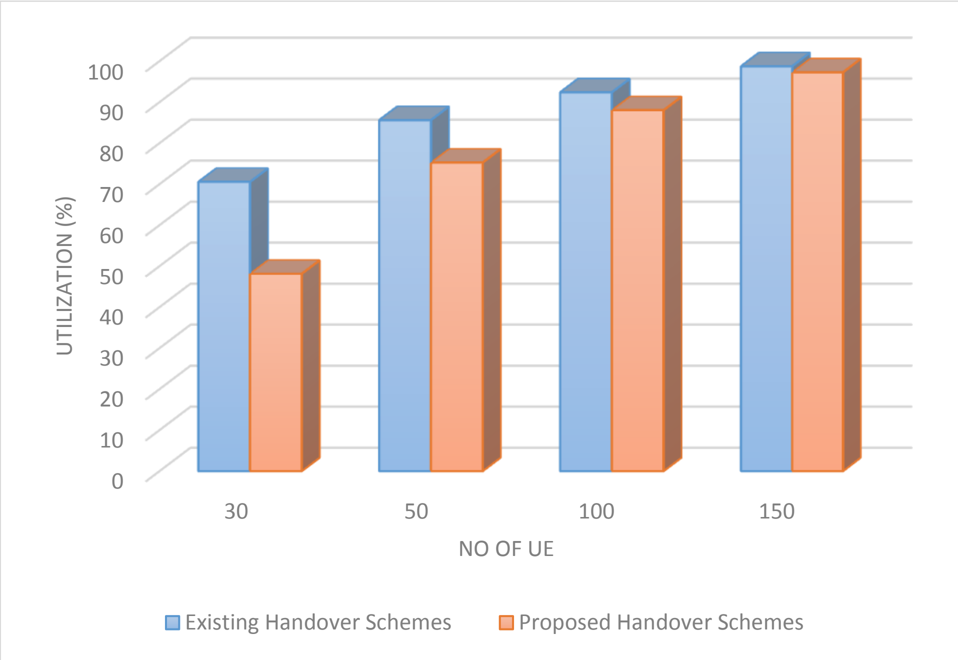

Fig. 32 Utilization (%) of Resource Blocks

2. Comparison of System throughput between proposed and existing handover schemes

Fig 33 illustrates the throughput (Mbps) between proposed and existing handover schemes. The trend of both handover schemes is increasing when number of UEs are increasing. It means when more UEs are entering in the system, more data packets are transmitted successfully. We observed that, when there are less number of UEs are in the system, in both schemes the throughput is almost same. The reason is when load is low, there are enough utilisation of RBs are left, therefore both schemes are efficiently distribute radio resources among UEs. But when number of UE is increased the interference level become increased and the division of radio consumption is critical among UEs, in such case the proposed handover scheme is efficiently work, that's why the throughput sharply increased as compere with the existing handover schemes.

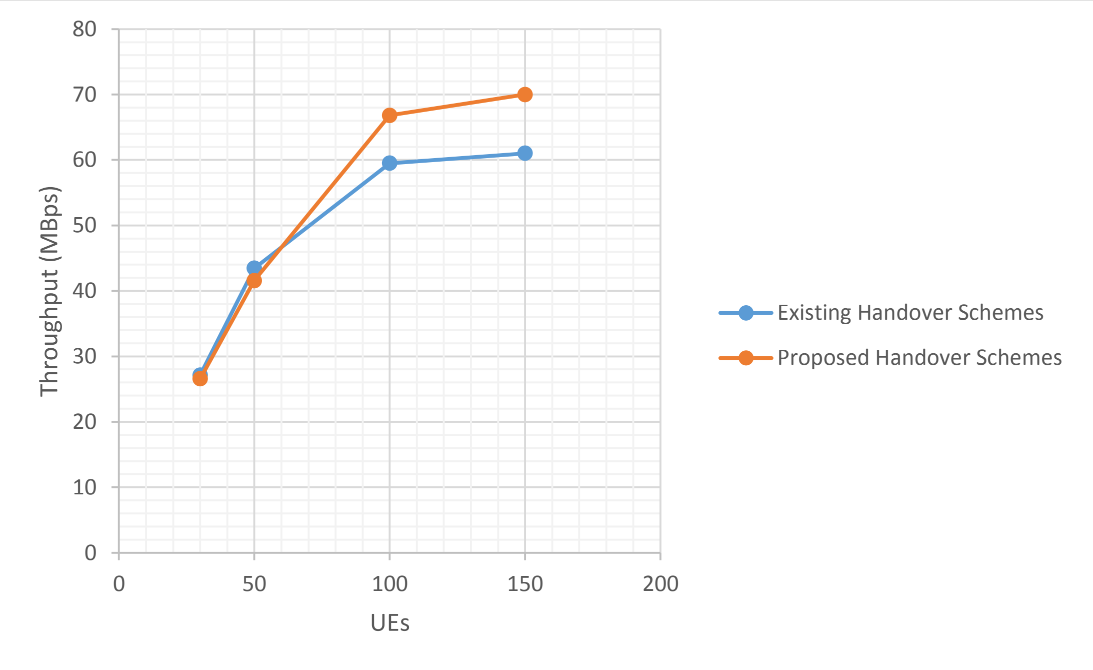

Fig. 33 System throughput of Proposed and Existing Handover Schemes

We observed that in both cases until 50 number of UEs the throughput is almost same about 41.56 Mbps, but when more number of users are entering in the system, the proposed handover scheme has 66.8Mbps and existing handover scheme has 59.5Mbps. When the number of Users increased up to certain level (i.e. 100) the results shows for both cases fixed throughput behaviour. This is because the saturated conditions of resource block as mentioned in pervious results.

Summary of Chapter 6

A new CoMP-JT based handover scheme is proposed for optimizing feedback and resource sharing process in LTE-A during handover process. For this purpose, UEs are categorised into CoMP UE and Non CoMP UE on basis of signal measurements such as RSRP and RSRQ. Furthermore, always avoid to trigger CoMP JT at cell centre location because the interference level is very low. Once the UE experience low signal measurements, CoMP JT is triggered, in this mode the selection of eNBs and resource sharing among UE is discussed in details in this chapter. At the end, the experimental results are discussed and compare results between proposed and existing handover schemes.

Chapter 7: Conclusions and Recommendations

7. Introduction

This chapter contains precise discussion on research material included in the thesis. Also concluding remarks on proposed handover algorithms are part of this discussion. At the end, the possible improvements in future works are discussed in this chapter.

7.1. Conclusions

The present research thesis consists of coordinated multipoint (CoMP) technique of LTE-A, that is used to determine effective and reliable solutions of existing problems encountered by wireless networks. These existing problems include Inter-cell Interference caused by neighbouring cells at cell edge region. Due to ICI, the mobility of UEs at cell edge region is challenging task for wireless networks because according to Cisco's global mobile data traffic report [17] billions of users are becoming part of wireless networks every year and they predicted it will reach to 11.6 billion by 2021. Therefore, to accommodate these users, the network infrastructure become more and more complex and consisting on many macro and micro cell. These issues; large number of users and complex infrastructure causes adverse situation for cell edge users in wireless networks. As a result of these issues the number of unnecessary handovers increased and throughput degraded at cell edge. Thus, the main emphasis of present research is on cell edge users for finding solutions of unnecessary handovers and increase overall system throughput. For this purpose, in present research the literature on handover is exposed and establish CoMP technique is helpful to resolve above mentioned issues. Although, CoMP technique has many good solutions of existing issues but it has many drawbacks such as excessive feedback and radio resource consumptions. This technique is many times used in handover algorithms by different authors but they did not discuss drawbacks of this technique in details. The present research contains answers and solutions of all these drawbacks. In this context, two handover algorithms are proposed; 1) An Efficient CoMP-based Handover Scheme for Next Generation Wireless Networks to reduce unnecessary number of handovers at cell edge and 2) Optimised Feedback and Resource Sharing Process during CoMP-JT based Handover in LTE-A Systems for Cell Edge User.

In first algorithm, A new handover scheme for reducing unnecessary handover decisions is proposed, based on CoMP and signal measurements RSRP and RSRQ of UE. In addition, the CoMP mode is triggered when UE receives signal power RSRP lower than threshold level. In conventional handover schemes, on same threshold level of RSRP, the handover is triggered. In conventional handover scheme during handover, control of UE is transferred from serving eNB to target eNB. In CoMP mode, the control is not transferred to target cell but the UE start progressively receives data from multiple eNBs according to the CoMP technique. Thus, following CoMP mode, the handover mode is activated to further check the RSRP signal power along with RSRQ signal quality to make sure acceptable conditions of network prior to taking final handover decision. Moreover, Comparisons were carried out on handover initialisation decisions of the proposed handover scheme versus conventional handover schemes. It was observed that the proposed handover scheme is more effective than the earlier ones, having less number of handover decisions and a reduced percentage of unnecessary ones

In second algorithm, A new CoMP-JT based handover scheme is proposed for optimising feedback and resource sharing process in LTE-A during handover process. In CoMP technique, feedback report and resource sharing are always debatable and considered drawbacks of CoMP technique. To overcome these drawbacks, different approaches are used in proposed algorithm such as; UE are categorised into CoMP UE and Non-CoMP UE, always select eNB having highest RSRP and RSRQ along with capacity, and discussed a method for resource sharing among CoMP UE and Non-CoMP UE. The simulation results shows that these approaches are effective and increased system performance up to certain level because when the system become saturated the experimental results shows that the performance of proposed and existing system are behave like same. Moreover, comparisons were carried out on utilisation of resource blocks and overall system throughput of the proposed handover scheme versus existing handover schemes. It was observed that the proposed handover scheme is more effective than the earlier ones, having better utilization of resource blocks and throughput as compare with existing handover schemes.

7.2. Recommendations for Future Work

Although, the present research on handover resolve many problems but there are many areas and important issues need attentions. Some of them are listed below for future work.

1. In chapter 4, figure 18 showed the wrap around function, the simulation results of chapter 6 are based on this function because Downlink LTE simulator used this function. Actually the research is based on cell edge area, but this wrap around function is not covered all edges of cells, they include only edges of cells they are located at the centre. That's why the present research results and existing results are having minor differences. If this function updated inside the simulator with help of mathematically equations then the results will be more accurate and having big difference with existing research.
2. The chapter 6 contain only few results because of above mentioned problem of LTE simulator. If the problem overcome, then the system delay, utilization of resource block at cell edge, and throughput at cell edge can calculate and improve as compare with existing handover algorithms.

3. Wireless networks are facing many issues of fast speeding UEs and the scenario is more complicated when at time on same speed more than one (even in 100) UEs need to perform handover procedure. This happened in fast moving vehicles like bullets trains. There are many trains launched with over 200 miles speed [97], so in such situation the handover procedure become more complicated. Therefore the future study is based on finding efficient solution for users traveling on fast speed vehicle with help of CoMP technique.

4. The probability of handover failure is increased on peak time at overcrowded places such as shopping malls and stadiums. Normally, the infrastructure of networks is extended in such locations to boost the signal powers to increase the network performance. But with all these solutions, still people complained the call drops in such area [98]. Therefore the future study is also follow such cases and find solution on basis of CoMP technique.

Bibliography

[1] 3gpp.org. (2018). ITU-R Confers IMT-Advanced (4G) Status to 3GPP LTE. [Online] Available at: http://www.3gpp.org/news-events/3gpp-news/1319-ITU-R-Confers-IMT-Advanced-4G-Status-to-3GPP-LTE [Accessed: 04-Apr-2017].

[2] E. R. Cellan-Jones Rory, "How will the 5G network change the world?," *BBC News*, 01-Dec-2014.

[3] OFCOM, "Report: 4G Capacity Gains Final report-Appendices," Published by Real Wireless Ltd. 27-Jan-2011. [Online] Available: https://www.ofcom.org.uk/__data/assets/pdf_file/0038/74999/4gcapacitygainsfinalreporta1.pdf. [Accessed: 16-May-2017].

[4] International Telecommunication Union "ITU towards 'IMT for 2020 and beyond,'" *ITU*. [Online]. Available: http://www.itu.int:80/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Pages/default.aspx. [Accessed: 04-Apr-2017].

[5] GSM Network 2020 "Unlocking Commercial Opportunities from 4G Evolution to 5G." [Online]. Available: http://www.gsma.com/futurenetworks/wp-content/uploads/2017/03/704_GSMA_unlocking_comm_opp_report_v5.pdf. [Accessed: 16-May-2017].

[6] A. E. M. Taha, N. A. Ali, and H. S. Hassanein, *LTE, LTE-Advanced and WiMAX: Towards IMT-Advanced Networks*. John Wiley & Sons, 2011.

[7] J. Wannstrom "LTE-Advanced." Published by 3GPP: The Mobile Broadband Standard, June 2013 [Online]. Available: http://www.3gpp.org/technologies/keywords-acronyms/97-lte-advanced. [Accessed: 04-Apr-2017].

[8] T. Okamawari, H. Hayashi, and T. Fujii, "A Proposal on Network Control Architecture for CoMP JT with IP Network between eNBs," in *2012 IEEE 75th Vehicular Technology Conference (VTC Spring)*, 2012, pp. 1–5.

[9] T. Okamawari, L. Zhang, A. Nagate, H. Hayashi, and T. Fujii, "Design of Control Architecture for Downlink CoMP Joint Transmission with Inter-eNB Coordination in Next Generation Cellular Systems," in *2011 IEEE Vehicular Technology Conference (VTC Fall)*, 2011, pp. 1–5.

[10] S. Sesia, M. Baker, and I. Toufik, *LTE - The UMTS Long Term Evolution: From Theory to Practice*. John Wiley & Sons, 2011.

[11] A. Ghosh and R. Ratasuk, *Essentials of LTE and LTE-A*. Cambridge University Press, 2011.

[12] J. Lee *et al.*, "Coordinated multipoint transmission and reception in LTE-advanced systems," *IEEE Commun. Mag.*, vol. 50, no. 11, pp. 44–50, Nov. 2012.

[13] D. Lee *et al.*, "Coordinated multipoint transmission and reception in LTE-advanced: deployment scenarios and operational challenges," *IEEE Commun. Mag.*, vol. 50, no. 2, pp. 148–155, Feb. 2012.

[14] I. Shayea, M. Ismail, and R. Nordin, "Advanced handover techniques in LTE-Advanced system," in *2012 International Conference on Computer and Communication Engineering (ICCCE)*, 2012, pp. 74–79.

[15] J. Chang, Y. Li, S. Feng, H. Wang, C. Sun, and P. Zhang, "A Fractional Soft Handover Scheme for 3GPP LTE-Advanced System," in *2009 IEEE International Conference on Communications Workshops*, 2009, pp. 1–5.

[16] W. Zhang, H. Ro, C. Liu, I. Hoffman, and K. Ungar, “Design and optimization of a dual-HPGe gamma spectrometer and its cosmic veto system for low-level environmental radioactivity monitoring,” *IEEE Trans. Nucl. Sci.*, pp. 1–1, 2017.

[17] Cisco Mobile VNI “Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021 White Paper - Cisco.” March 28, 2017 [Online]. Available: http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html. [Accessed: 16-May-2017].

[18] G. Piro, L. A. Grieco, G. Boggia, F. Capozzi, and P. Camarda, “Simulating LTE Cellular Systems: An Open-Source Framework,” *IEEE Trans. Veh. Technol.*, vol. 60, no. 2, pp. 498–513, Feb. 2011.

[19] “NS3 LTE Simulation Projects | Sample NS3 LTE Project Code,” *Ns3 Projects*.

[20] “Vienna LTE-A Simulators – nt.tuwien.ac.at.” .

[21] H. A. M. Ramli, K. Sandrasegaran, R. Basukala, and L. Wu, “Modeling and simulation of packet scheduling in the downlink long term evolution system,” in *2009 15th Asia-Pacific Conference on Communications*, 2009, pp. 68–71.

[22] J. Han and B. Wu, “Handover in the 3GPP long term evolution (LTE) systems,” in *2010 Global Mobile Congress*, 2010, pp. 1–6.

[23] M. Pagani, *Mobile and Wireless Systems Beyond 3G: Managing New Business Opportunities*. Idea Group Inc (IGI), 2005.

[24] L. D. Olavarrieta and A. A. Nava, “Wireless communications: a bird’s eye view of an emerging technology,” in *IEEE International Symposium on Communications and Information Technology, 2004. ISCIT 2004.*, 2004, vol. 1, pp. 541–546 vol.1.

[25] U. Bhuvan, *Handbook of Research in Mobile Business: Technical, Methodological, and Social Perspectives: Technical, Methodological, and Social Perspectives*. Idea Group Inc (IGI), 2006.

[26] S. DongBack, *Evolution and Standardization of Mobile Communications Technology*. IGI Global, 2013.

[27] D. M. (Ph.D.), *The Telephone: The Life Story of a Technology*. Greenwood Publishing Group, 2006.

[28] J. Doherty, *Wireless and Mobile Device Security*. Jones & Bartlett Publishers, 2015.

[29] OECD, *Mobile Phones: Pricing Structures and Trends*. OECD Publishing, 2000.

[30] Garg, *Wireless Network Evolution: 2G to 3G*. Pearson Education India, 2002.

[31] A. Boukerche, *Handbook of Algorithms for Wireless Networking and Mobile Computing*. CRC Press, 2005.

[32] N. Tripathi and J. H. Reed, *Cellular Communications: A Comprehensive and Practical Guide*. John Wiley & Sons, 2014.

[33] M. A. Resources Information, *Data Mining: Concepts, Methodologies, Tools, and Applications: Concepts, Methodologies, Tools, and Applications*. IGI Global, 2012.

[34] J. Hoy, *Forensic Radio Survey Techniques for Cell Site Analysis*. John Wiley & Sons, 2015.

[35] J. Hoy, *Forensic Radio Survey Techniques for Cell Site Analysis*. John Wiley & Sons, 2015.

[36] R. Zhang, L. Cai, and J. Pan, *Resource Management for Multimedia Services in High Data Rate Wireless Networks*. Springer, 2016.

[37] U. Bhuvan, *Handbook of Research in Mobile Business: Technical, Methodological, and Social Perspectives: Technical, Methodological, and Social Perspectives*. Idea Group Inc (IGI), 2006.

[38] J. Cartman and R. Ting, *Strategic Mobile Design: Creating Engaging Experiences*. Peachpit Press, 2008.

[39] J. Li, M. Wen, X. Jiang, and Y. Yan, “Novel control signal detection for high-rate transmission in LTE-OFDM systems,” in *2016 IEEE International Conference on Signal Processing, Communications and Computing (ICSPCC)*, 2016, pp. 1–4.

[40] S. K. Das, *Mobile Terminal Receiver Design: LTE and LTE-Advanced*. John Wiley & Sons, 2017.

[41] 3GPP, “LTE Overview.” [Online]. Available: http://www.3gpp.org/technologies/keywords-acronyms/98-lte. [Accessed: 16-May-2017].

[42] “Communications standards news,” *IEEE Commun. Mag.*, vol. 53, no. 3, pp. 6–9, Mar. 2015.

[43] P. Samuel, *Next Generation Mobile Networks and Ubiquitous Computing*. Idea Group Inc (IGI), 2010.

[44] J. Sultan, M. Ismail, N. Misran, and K. Jumari, “Spectral Efficiency Evaluation of Downlink Mobile Multi-hop Relay Systems Employing Macro Diversity Handover Technique,” presented at the International Journal of Computer Science and Network Security, 2008, vol. Vol 8 No 5.

[45] M. M.A, *Handbook of Research on Progressive Trends in Wireless Communications and Networking*. IGI Global, 2014.

[46] N. Chilamkurti, S. Zeadally, and H. Chaouchi, *Next-Generation Wireless Technologies: 4G and Beyond*. Springer Science & Business Media, 2013.

[47] S. Stefania, T. Issam, and B. Matthew, *LTE - The UMTS Long Term Evolution: From Theory to Practice*. John Wiley & Sons, 2011.

[48] R. Kreher and K. Gaenger, *LTE Signaling: Troubleshooting and Performance Measurement*. John Wiley & Sons, 2016.

[49] F. Afroz, R. Subramanian, R. Heidary, K. Sandrasegaran, and S. Ahmed, "SINR, RSRP, RSSI and RSRQ Measurements in Long Term Evolution Networks," Aug. 2015.

[50] M. Sauter, *From GSM to LTE: An Introduction to Mobile Networks and Mobile Broadband*. John Wiley & Sons, 2010.

[51] R. P. Ray, L. Tang, and the Chongqing University of Posts and Telecommunications, Chongqing, China, "Hysteresis Margin and Load Balancing for Handover in Heterogeneous Network," *Int. J. Future Comput. Commun.*, vol. 4, no. 4, pp. 231–235, 2015.

[52] A. L. Yusof, N. Ya'acob, and M. T. Ali, "Hysteresis margin for handover in Long Term Evolution (LTE) network," in *2013 International Conference on Computing, Management and Telecommunications (ComManTel)*, 2013, pp. 426–430.

[53] P. Stavroulakis, *TErrestrial Trunked RAdio - TETRA: A Global Security Tool*. Springer Science & Business Media, 2007.

[54] J. Kim, L. Geunhyung, and Hoh Peter In, "Adaptive Time-to -Trigger Scheme for Optimizing LTE Handover," *Int. J. Control Autom.*, vol. 7, no. 4, pp. 35–44, 2014.

[55] C. C. Lin, K. Sandrasegaran, and S. Reeves, “Handover algorithm with joint processing in LTE-advanced,” in *2012 9th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology*, 2012, pp. 1–4.

[56] “TS 136 300 - V10.5.0 - LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (3GPP TS 36.300 version 10.5.0 Release 10) - ts_136300v100500p.pdf.” [Online]. Available: http://www.etsi.org/deliver/etsi_ts/136300_136399/136300/10.05.00_60/ts_136300v100500p.pdf. [Accessed: 16-May-2017].

[57] European Telecommunications Standards Institute, *TS 136 300 - V11.5.0 - LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (3GPP TS 36.300 version 11.5.0 Release 11)*. 2013.

[58] D. Ali, *Self-Organized Mobile Communication Technologies and Techniques for Network Optimization*. IGI Global, 2016.

[59] H. Patel, “RRM functions.” .

[60] S. Kasera and N. Narang, *3G Mobile Networks: Architecture, Protocols and Procedures Based on 3GPP Specifications for UMTS WCDMA Networks*. McGraw-Hill, 2005.

[61] ANRITSU, “3GPP:LTE Resource Guide.” [Online]. Available: http://web.cecs.pdx.edu/~fli/class/LTE_Reource_Guide.pdf. [Accessed: 16-May-2017].

[62] “3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-

UTRA);Further advancements for E-UTRA physical layer aspects, (Release 9), 2010-03.” [Online]. Available: http://www.qtc.jp/3GPP/Specs/36814-900.pdf. [Accessed: 16-May-2017].

[63] T. Biermann, L. Scalia, C. Choi, H. Karl, and W. Kellerer, “CoMP clustering and backhaul limitations in cooperative cellular mobile access networks,” *Pervasive Mob. Comput.*, vol. 8, no. 5, pp. 662–681, Oct. 2012.

[64] S. Sun, Q. Gao, Y. Peng, Y. Wang, and L. Song, “Interference management through CoMP in 3GPP LTE-advanced networks,” *IEEE Wirel. Commun.*, vol. 20, no. 1, pp. 59–66, Feb. 2013.

[65] C. C. Lin, K. Sandrasegaran, X. Zhu, and Z. Xu, “Limited Comp Handover Algorithm For LTE-Advanced,” *Journal of Engineering*, 2013. [Online]. Available: https://www.hindawi.com/journals/je/2013/462416/. [Accessed: 18-Oct-2017].

[66] A. Marotta *et al.*, “Performance evaluation of CoMP coordinated scheduling over different backhaul infrastructures: A real use case scenario,” in *2016 IEEE International Conference on the Science of Electrical Engineering (ICSEE)*, 2016, pp. 1–5.

[67] A. Technologies, *LTE and the Evolution to 4G Wireless: Design and Measurement Challenges*. John Wiley & Sons, 2013.

[68] T. Bu, L. Li, and R. Ramjee, “Generalized Proportional Fair Scheduling in Third Generation Wireless Data Networks,” in *Proceedings IEEE INFOCOM 2006. 25TH IEEE International Conference on Computer Communications*, 2006, pp. 1–12.

[69] R. Kwan, C. Leung, and J. Zhang, “Proportional Fair Multiuser Scheduling in LTE,” *IEEE Signal Process. Lett.*, vol. 16, no. 6, pp. 461–464, Jun. 2009.

[70] Ronak D. Trivedi, “Comparison of Different Scheduling Algorithm for L TE,” *International Journal of Emerging Technology and Advanced Engineering*.

[71] P. Santi, *Mobility Models for Next Generation Wireless Networks: Ad Hoc, Vehicular and Mesh Networks*. John Wiley & Sons, 2012.

[72] EC-Council, *Computer Forensics: Investigation Procedures and Response (CHFI)*. Cengage Learning, 2016.

[73] “LTE System Toolbox - MATLAB.” [Online]. Available: https://uk.mathworks.com/products/lte-system.html. [Accessed: 19-Nov-2017].

[74] “SimuLTE - LTE User Plane Simulator for OMNeT++ and INET.” [Online]. Available: http://simulte.com/. [Accessed: 19-Nov-2017].

[75] “Specification # 25.814.” [Online]. Available: https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=1247. [Accessed: 19-Nov-2017].

[76] A. G. O. Lugo, F. A. C. Prez, and G. H. Valdez, “Investigating the boundary effect of a multimedia TDMA personal mobile communication network simulation,” in *IEEE 54th Vehicular Technology Conference. VTC Fall 2001. Proceedings (Cat. No.01CH37211)*, 2001, vol. 4, pp. 2740–2744 vol.4.

[77] L. Cheng-Chung, “Handover Mechanisms in 3GPP Long Term Evolution (LTE),” University of Technology, Sydney, 2013.

[78] M. Gudmundson, “Correlation model for shadow fading in mobile radio systems,” *Electron. Lett.*, vol. 27, no. 23, pp. 2145–2146, Nov. 1991.

[79] K. Kim, G. M. Yeo, B. H. Ryu, and K. Chang, “Interference Analysis and Subchannel Allocation Schemes in Tri-Sectored OFDMA Systems,” in *2007 IEEE 66th Vehicular Technology Conference*, 2007, pp. 1857–1861.

[80] X. Zhang and X. Zhou, *LTE-Advanced Air Interface Technology*. CRC Press, 2012.

[81] J. T. J. Penttinen, *The LTE-Advanced Deployment Handbook: The Planning Guidelines for the Fourth Generation Networks*. John Wiley & Sons, 2016.

[82] C.-C. Lin, K. Sandrasegaran, X. Zhu, and Z. Xu, "On the performance of capacity integrated CoMP handover algorithm in LTE-Advanced," in *2012 18th Asia-Pacific Conference on Communications (APCC)*, 2012, pp. 871–876.

[83] X. W. Li and J. Wang, "The Optimized Method of Reducing Unnecessary Handover in LTE System," in *2013 Third International Conference on Instrumentation, Measurement, Computer, Communication and Control*, 2013, pp. 1224–1227.

[84] O. Teyeb, A. Centonza, K. Dimou, and W. Müller, "Handover robustness in cellular radio communications," US20140148174 A1, 29-May-2014.

[85] "Unnecessary handover minimization in two-tier heterogeneous networks - IEEE Conference Publication." [Online]. Available: http://ieeexplore.ieee.org/document/7888692/. [Accessed: 01-Nov-2017].

[86] C. C. Lin, K. Sandrasegaran, X. Zhu, and Z. Xu, "Performance evaluation of capacity based CoMP handover algorithm for LTE-Advanced," in *The 15th International Symposium on Wireless Personal Multimedia Communications*, 2012, pp. 236–240.

[87] H. Lee, D. Kim, B. Chung, and H. Yoon, "Adaptive Hysteresis Using Mobility Correlation for Fast Handover," *IEEE Commun. Lett.*, vol. 12, no. 2, pp. 152–154, Feb. 2008.

[88] Z. Becvar and P. Mach, "Adaptive Hysteresis Margin for Handover in Femtocell Networks," in *2010 6th International Conference on Wireless and Mobile Communications*, 2010, pp. 256–261.

[89] S. Ahmadi, *LTE-Advanced: A Practical Systems Approach to Understanding 3GPP LTE Releases 10 and 11 Radio Access Technologies*. Academic Press, 2013.

[90] S. K. Das, *Mobile Terminal Receiver Design: LTE and LTE-Advanced*. John Wiley & Sons, 2017.

[91] K. Meresa, *Performance evaluation of channel estimation techniques for LTE downlink system*. Lulu.com.

[92] T. Jansen, I. Balan, J. Turk, I. Moerman, and T. Kurner, "Handover Parameter Optimization in LTE Self-Organizing Networks," in *2010 IEEE 72nd Vehicular Technology Conference - Fall*, 2010, pp. 1–5.

[93] P. Atanasov and Z. Kiss'ovski, "Investigations of the signal path loss in 4G LTE network," *Bulg. J. Phys. Print*, vol. 40, no. 3, pp. 265–268, 2013.

[94] H. Xian, W. Muqing, M. Jiansong, and Z. Cunyi, "The impact of channel environment on the RSRP and RSRQ measurement of handover performance," in *2011 International Conference on Electronics, Communications and Control (ICECC)*, 2011, pp. 540–543.

[95] "LTE Radio Link Budgeting and RF Planning - lteencyclopedia." [Online]. Available: https://sites.google.com/site/lteencyclopedia/lte-radio-link-budgeting-and-rf-planning. [Accessed: 06-Nov-2017].

[96] S. Kaneko, M. Fushiki, M. Nakano, and Y. Kishi, "BS-Cooperative Scheduler for a Multi-Site Single-User MIMO Cellular System," in *2010 IEEE 72nd Vehicular Technology Conference - Fall*, 2010, pp. 1–5.

[97] "Watch: China launches the world's fastest bullet train." [Online]. Available: http://www.telegraph.co.uk/news/2017/09/21/watch-china-launches-worlds-fastest-bullet-train/. [Accessed: 18-Nov-2017].

[98] "Call Drops: The Reasons and Possible Solutions to ensure #NoCallDrops." [Online]. Available: https://telecomtalk.info/call-drops-the-reasons-and-possible-solutions-to-ensure-nocalldrops/142422/. [Accessed: 18-Nov-2017].